B.C. 7

# Canada–B.C. Conservation and Renewable Energy Demonstrations

Energy, Mines and Resources Canada
Conservation and Renewable Energy Branch

Energie, Mines et Ressources Canada
Bureau de la conservation et des énergies renouvelable

Province of British Columbia

Ministry of Energy, Mines and Petroleum Resources
CONSERVATION AND TECHNOLOGY DIVISION

# LOW ENERGY HOUSING

# DEMONSTRATION PROJECT

CONSERVATION & RENEWABLE ENERGY BRANCH

MINISTRY OF ENERGY, MINES AND PETROLEUM RESOURCES

VANCOUVER, B.C.

## CANADA/BRITISH COLUMBIA CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

The availability of secure and affordable energy supplies is a subject of national concern. It is an accepted fact that our primary energy sources - oil and natural gas - are becoming less accessible and more costly. However, Canada is well-endowed with non-renewable and alternative resources that can provide a bridge into the future.

To this end, the governments of British Columbia and Canada have entered into a Conservation and Renewable Energy Demonstration Agreement. The Agreement is dedicated to the development and demonstration of conservation and renewable technologies.

The objectives of CREDA are:

- To develop and demonstrate promising new technologies, which, when widely adopted, will exploit renewable resources, conserve energy and/or use energy more efficiently.
- To develop broad public awareness of the potential of renewable energy and conservation technology.
- To provide opportunities for the commercial application of the technologies within B.C.
- To create economic spin-off benefits for manufacturing, industry and commerce.
- To create employment in new or existing energy-related industries.

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## EXECUTIVE SUMMARY

The Low Energy Housing Demonstration Project, which was initiated in 1979 under the jointly funded Federal/Provincial Conservation and Renewable Energy Demonstration Agreement (CREDA), attempted to demonstrate and compare the thermal performance of passive solar heating and super-insulation in new single family residential housing.

A total of six houses were built under the project in Saanich and Richmond, B.C. At each location, a control house of standard construction, a Solar house employing passive solar technology and a Conserver house emphasizing high insulation levels were built.

After construction was complete, open houses were held in the Solar and Conserver houses to demonstrate their innovative features to the public. For more technical information, seminars were held for builders and designers.

The houses were then put up for sale and were monitored for energy use after occupancy. The actual monitored fuel consumption did not allow meaningful comparisons of energy use between the different houses due to the high variability in occupant lifestyles from house to house.

However, based on a long term predicted fuel consumption for the Richmond houses under standardized interior conditions, the Control, Solar and Conserver houses would consume 117 GJ, 48GJ and 40 GJ, respectively, which translates into a 59% and 66% energy savings, respectively, over the Control.

## CONCLUSIONS AND RECOMMENDATIONS

1. The conservation measures adopted in the low energy houses do, in fact, appear to result in significant energy savings. Based on long term predicted energy use, the Richmond Solar and Conserver houses will result in savings of 59% and 66%, respectively. However, it is not clear that the Conserver approach will outperform the Solar approach on a general, province wide basis. Variables such as design, climate, solar access and occupancy lifestyles preclude one from drawing this conclusion. The optimal design will be sensitive to the characteristics of the site and lifestyle of the occupants and will draw from conserver and solar concepts in an optimal combination. The data gathered, however, will have significance by adding to the pool of data which may eventually allow more general conclusions to be made.

   In general, however, it would be safe to say that a relatively high degree of insulation and air sealing is more justified in terms of energy savings than passive solar measures which are more sophisticated than simple reorientation of windows.

2. Of the measures adopted in this project, it appears that increasing the insulation levels of the ceiling and the floor over the crawlspace represent the most cost- effective measures. Increasing the wall insulation level with fibreglass batts also appears attractive economically in electrically heated homes. Installing insulated doors in an electrically heated house is also cost-effective.

3. In replicating a project of similar nature to this one, it is recommended that greater control be established by the organizing agency. An arrangement whereby the houses were owned outright by the agency or where the houses were pre-sold would provide greater design and quality control.

4. Public response to this project has been generally positive as evidenced by the turnout at seminars and open houses and by the extent of media coverage. The actual impact of this project on the housing industry, however, is difficult to determine and has no doubt been hampered by the poor housing market.

5. The experience of this project has demonstrated the need for adequate on-site training of the insulation/vapour barrier subtrade and as well as other subtrades such as electrical, plumbing, heating and framing. Close supervision during construction to coordinate the subtrades and to provide instruction on the principles and techniques of the air/vapour barrier is an essential part of this training and is required to ensure quality constructon. As these techniques become more common in the industry, the amount of training and supervision required will diminish.

6. Marketing efforts to sell the low energy houses have shown that people, in general, have not been sufficiently sensitized to energy costs to make the extra investment in the conservation features employed. This points out the need to provide people with an energy conserving house at a price they are willing to pay. Ways in which to accomplish this, as indicated by the builders, include the use of standard building components and practices where possible, elimination of low payback items such as triple glazing, air-lock vestibules and greenhouses or atriums unless desired by a specific client and substitution of lower cost materials such as fibreglass batt insulation rather than rigid extruded polystyrene and linoleum rather than clay tile flooring.

   Marketing considerations also dictate that a low energy house design address other factors upon which people make house buying decisions such as comfort, utility, affordability and compatibility with lifestyle.

7. While rapidly growing more knowledgeable about residential energy conservation, the general public cannot be expected to develop sophisticated technical expertise. Therefore energy conserving designs should require only basic understanding and participation by the occupant in order to operate the low energy house efficiently and reliably. Examples of where active participation of the occupant is required are the use of night insulation, opening and closing of greenhouse vents and adjustment of temperature or humidity control setpoints.

8. The demonstration project has indicated the potential for improved and new products. One need in particular is the development of furnaces suitable for low energy houses. Current gas furnaces on the market are oversized. Cost reductions should be possible for gas condensing furnaces, air to air heat exchangers, triple glazed windows and night insulation with design and production improvements. Wider acceptance of these products in the marketplace will result in greater savings through economies of scale.

# 1. INTRODUCTION

The incorporation of energy efficient measures in new housing is recognized as the most cost-effective means to reduce future housing stock energy consumption as opposed to complicated retrofits. State-of-the-art techniques in low energy housing have resulted in practically zero space heating costs. In implementing more cost-effective measures, one can reasonably expect savings of 60-70%. The implications for potential savings in the residential sector is obvious, making energy conservation in new housing of primary importance as new houses built today will be consuming energy for many years to come.

## 1.1 Background

Prior to the inception of the Low Energy Housing Demonstration Project in 1979, two distinct schools of thought were emerging with regard to the most cost-effective way to reduce residential heating costs. The concept of passive solar heating was fairly well established at the time and growing in acceptance. The super-insulation approach, however, which emphasized reduced heating demand as popularized by the Saskatchewan Conservation House, was relatively new in concept but quickly gained acceptance as an alternative means to reduce heating costs.

Although relatively high insulation levels were generally regarded as a pre-requisite for good solar design, controversy existed over the appropriate approach in achieving the next level of energy savings. This comparison has been investigated fairly extensively in recent years as illustrated by the number of papers presented on this subject at the Sixth National Passive Solar Conference (1981).

The intent of this project was to demonstrate and compare the feasibility of the passive solar and super-insulation approaches (herein referred to as the Solar and Conserver approaches) in mass market housing within the B.C. context. This had not been previously demonstrated in this province.

It was recognized that actual design application might be better served, in many cases, by integrating solar and conserver concepts in an optional site specific combination. However, isolation of the two approaches did serve to meet the experimental and educational objectives of this project.

This project entailed the construction and monitoring of six houses in two different locations within the Province of B.C. The two sites selected included Saanich (just north of Victoria), and Richmond (a Vancouver suburb). At each site, a Solar, Conserver and Control house were constructed.

The intention was to monitor and compare the auxiliary energy consumption of each house. Preliminary computer simulations projected savings of approximately 80% of space heating costs over conventional construction.

This project was initiated in late 1979 following Joint Management Committee (CREDA) approval. The design contract with Solar Applications and Research was signed in November 1980. Builders were selected for the Saanich and Richmond sites during early 1981 and construction started during the summer of the same year. The Saanich houses were complete by November, 1981 with the Richmond houses completed by January, 1982. Problems in finding an appropriate builder and reaching a mutually agreeable design in Prince George delayed construction of houses at that site. Plans to construct these houses were subsequently cancelled.

## 1.2 Cooperating Parties

This project was funded under the joint Federal/Provincial Conservation and Renewable Energy Demonstration Agreement (CREDA) and was carried out in cooperation with the Housing and Urban Development Association of Canada, B.C. Council. Project management was administered by the Conservation and Renewable Energy Branch of the B.C. Ministry of Energy, Mines and Petroleum Resources. The house designs were developed by the firm Solar Applications and Research Ltd. who was awarded the design contract following a design competition. The builders selected were as follows:

| | |
|---|---|
| Saanich Solar house | Seaboard Construction Ltd. |
| Saanich Conserver house | Arbay Developments Ltd. |
| Saanich Control house | Tri-Rainbow Holdings Ltd. |
| Richmond Solar house | Nu-West Development Ltd. |
| Richmond Conserver house | Nu-West Development Ltd. |
| Richmond Control house | Nu-West Development Ltd. |

## 2. OBJECTIVES OF PROJECT

As a demonstration project, multiple objectives emerged which can be stated as follows:

1. Increase public awareness of the need and means to conserve energy in the residential sector;

2. Develop expertise within the residential construction industry of low energy housing construction methods; and

3. Compare energy consumption and cost-effectiveness of the conserver and solar approaches.

Market demand will ultimately provide the impetus for wide spread low energy housing construction. This demonstration project attempted to increase public awareness by demonstrating practical energy conservation measures, thus improving market demand.

Development of the necessary skills in the building trades is also important to widespread acceptance and construction of low energy housing. To this end, this project provided members of the construction industry the opportunity to gain hands-on experience in low energy housing construction. Others in the industry benefitted through the information transfer phase of this project.

Through monitoring these houses, it was hoped that empirical data could be gathered that would add to the existing data pool and eventually allow general conclusions to be drawn about the cost effectiveness of the solar and conserver approaches in B.C.

## 3. MINISTRY INVOLVEMENT

As mentioned previously, this project was funded under the joint Federal/Provincial Conservation and Renewable Energy Demonstration Agreement (CREDA).

The initial total project budget was $207,000 but was increased to $228,000 due to anticipated additional expenditures. The budget breakdown was as follows:

| | |
|---|---|
| Design | $ 40,000 |
| Incremental Construction Costs | 63,000 |
| Carrying Charges | 23,000 |
| Monitoring | 77,000 |
| Information Transfer | 25,000 |
| TOTAL BUDGET | $228,000 |

Due to the cancellation of the Prince George houses, actual expenditures totalled $150,000.

In order to attract builder interest and reduce their risks as the owner of these speculative houses, several forms of assistance were offered:

1. Incremental construction costs over and above that of conventional construction up to approximately $10,000 would be funded by CREDA. This amount was to be passed on to the purchaser as an inducement to counter potential consumer resistance to the higher cost of low energy housing.

2. Carrying charges for a period of one month would be covered so that an open house for this period of time could be held. The open house would meet the demonstrational purposes of this project as well as increase the chance for a sale due to the increased publicity. If, as a result of the open

house, a sale closing date was delayed the builder would not be penalized.

3. All design costs were covered by CREDA. The firm, Solar Applications and Research, was retained to develop the designs.

Subsequent to construction, the houses were monitored to provide data on their thermal performance. Solar Applications and Research was again retained for this purpose.

The project was administered by the Conservation and Renewable Energy Branch of the B.C. Ministry of Energy, Mines and Petroleum Resources. Project information services were also delivered by the Conservation and Renewable Energy Branch.

## 4. SITE SELECTION:

The Richmond and Saanich locations were chosen because of their proximity to major population centres. It was felt that this would create a higher profile and result in greater public impact.

The actual building lots chosen resulted from a combination of factors. Reasonable solar access was necessary for proper performance of the Solar house. The lots were required to be situated in close proximity to one another and similarly oriented so as not to invalidate monitoring efforts. The final factor in determining the lot location was the availability of lots to the chosen builder at the time of their selection.

The addresses of the chosen sites were:

Richmond

Solar House - 4326 Gander Place
Conserver House- 4340 Gander Place
Control House - 4308 Gander Place

Saanich

Solar House - 2364 Moore Place
Conserver House- 2358 Moore Place
Control House - 2352 Moore Place

## 5. DESIGNER SELECTION

A design competition was held in which requests for proposals were sent to several Vancouver area design firms who had prior experience in the field of low energy housing. Solar Applications and Research was awarded the design contract as a result of this competition.

## 6. BUILDER SELECTION

With the cooperation of local chapters of HUDAC who informed their members of the Low Energy Housing Demonstation project, meetings were held between Ministry staff and interested builders. Independent builders were chosen for each of the Saanich houses in order to spread the learning experience. A single major builder was chosen to construct all three Richmond houses. Lack of interest by other builders was the primary reason for making this choice. However, having one major builder overcame the problem of finding building lots located side by side, and allowed the construction of three similar houses but with different thermal characteristics.

## 7. DESIGNING THE HOUSES

The "Conserver" and "Solar" approaches referred to in this project coincide with the "light and tight" and "mass and glass" ideologies prevalent in low energy housing circles in the late 1970's. The "light and tight" approach or referred to as the Conserver approach in this project reduces auxiliary heating energy consumption primarily through high levels of insulation and taking measures to reduce air infiltration. The "mass and glass" or Solar approach employs the principles of passive solar heating including increased south facing glazing and thermal mass to reduce heating costs.

## 7.1 Requirements for Economic Comparisons

During the planning phase of this project, several factors came to light which guided the design of these houses and allowed valid economic comparisons to be made.

1. Overall payback should be kept within 20 years. Although this payback period may not be generally acceptable to private individuals and businesses, it was felt that this would allow innovative designs which would spark public interest and lead to lower cost versions through further design refinements and standardization.

2. Each Conserver and Solar house should have approximately equal incremental costs. Equal incremental costs would allow a more valid comparison of the thermal performance of each house. Incremental costs were defined to be those costs attributable to reducing auxiliary energy consumption and are over and above those of conventional housing standard. A target incremental cost of $10,000 for each house was established. A cost estimator was retained by the designers to provide an independent assessment of the incremental costs of the designs developed.

3. The heated floor area of each house in a particular location should roughly be the same. The floor areas were to be consistent with new mass market housing at that time and location. This was to facilitate greater validity in making comparisons and would make the houses of greater appeal to the general public.

4. The houses at each site should be similarly oriented and be in close proximity to one another to ensure similar climatic conditions for each house.

## 7.2 Builder Preferences

In addition to the design criteria required by the B.C. Ministry to allow valid economic comparisons, the chosen builders also had a major input into the final design. The builders were the actual owners of these speculative houses and, therefore, their input was necessary to provide a design which did not conflict too greatly with their construction practices and included features which they felt enhanced marketability.

The design process was, therefore, iterative in nature and was intended to provide designs which were practical to build and finally marketable to the public.

## 7.3 Other Criteria

Other criteria which emerged were architectural acceptability of the designs to the designer, flexibility to adapt to changes in future energy supply and the ability to allow ease of monitoring.

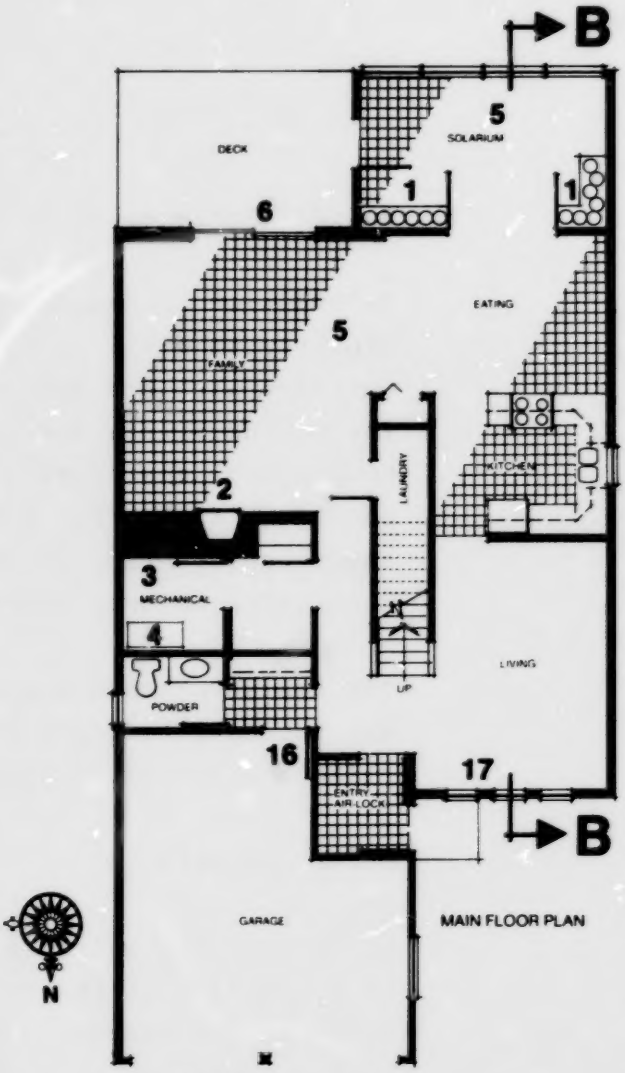
An example of flexibility to allow for changes in future energy supply was the decision to use an electric-forced air system rather than baseboard system in the Saanich houses. With the possibility of inexpensive natural gas being available to Vancouver Island in the near future, it was felt the heating system should have the flexibility to convert to natural gas.

Ease of monitoring was the reason behind choosing electric domestic hot water rather than natural gas in the Richmond houses. This allowed the domestic hot water energy consumption to be metered separately and easily.

Figure 1

# Richmond Solar House

1. Water storage cylinders for storing heat gains
2. Fireplace with outdoor combustion air and airtight doors
3. Thermally isolated mechanical room
4. Gas condensing furnace
5. Clay tile floor for storing solar heat gains
6. Insluating shade over double glazed south windows
7. Absorber plate for thermo-syphon solar hot water system
8. Solarium
9. Water storage cylinders
10. RSI-2.1 (R-12) batt insulation
    RSI-1.2 (R-7) rigid fibreglass insulation
11. Solar storage tank
12. RSI-7 (R-40) batt insulation
13. Clay tile floor over slab on grade
14. RSI-1.7 (R-10) extruded polystyrene
15. RSI-4.9 (R-28) batt insulation
16. Metal insulated core door
17. East, west & north windows — double glazed unit with interior storm window




## Main Floor Plan

## Cross-Section B-B

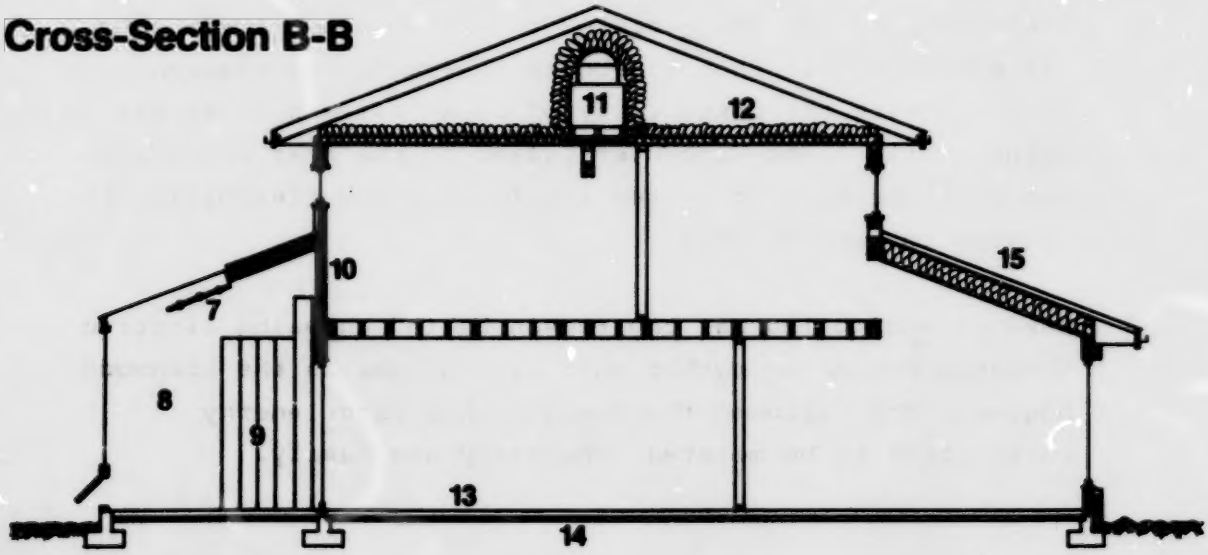
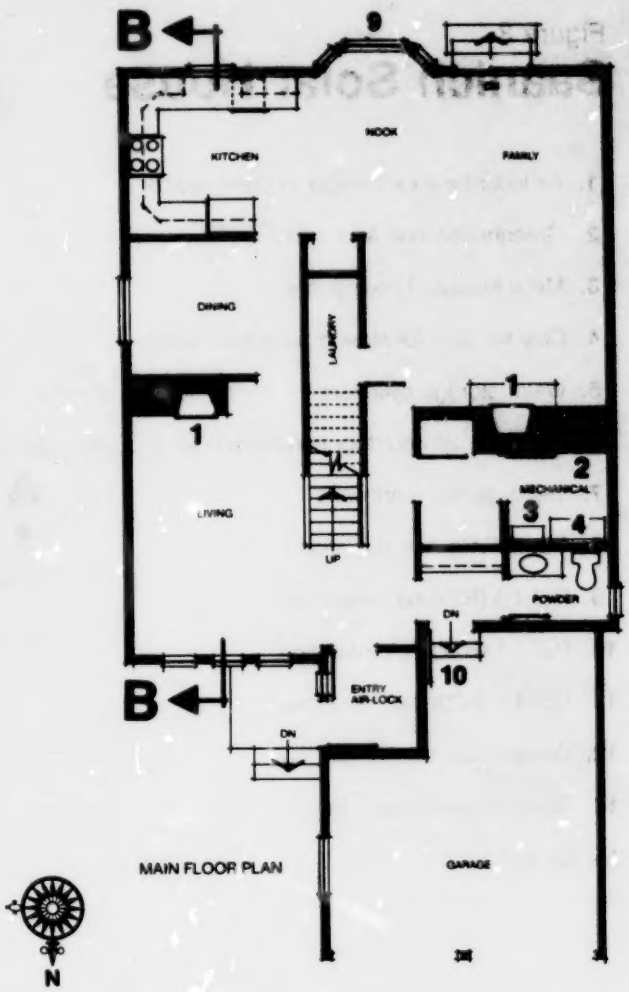


Figure 2

# Richmond Conserver House

1. Fireplace with outdoor combustion air and airtight doors
2. Thermally isolated mechanical room
3. Air-to-air heat exchanger
4. Gas condensing furnace
5. RSI-4.9 (R-28) batt insulation
6. RSI-4.9 (R-28) batt insulation
7. RSI-7 (R-40) batt insulation
8. RSI-3.5 (R-20) batt insulation
   RSI-1.2 (R-7) rigid fibreglass insulation
9. Triple glazing — double glazed unit with interior storm window
10. Metal insulated core door




## Main Floor Plan

## Cross-Section B-B

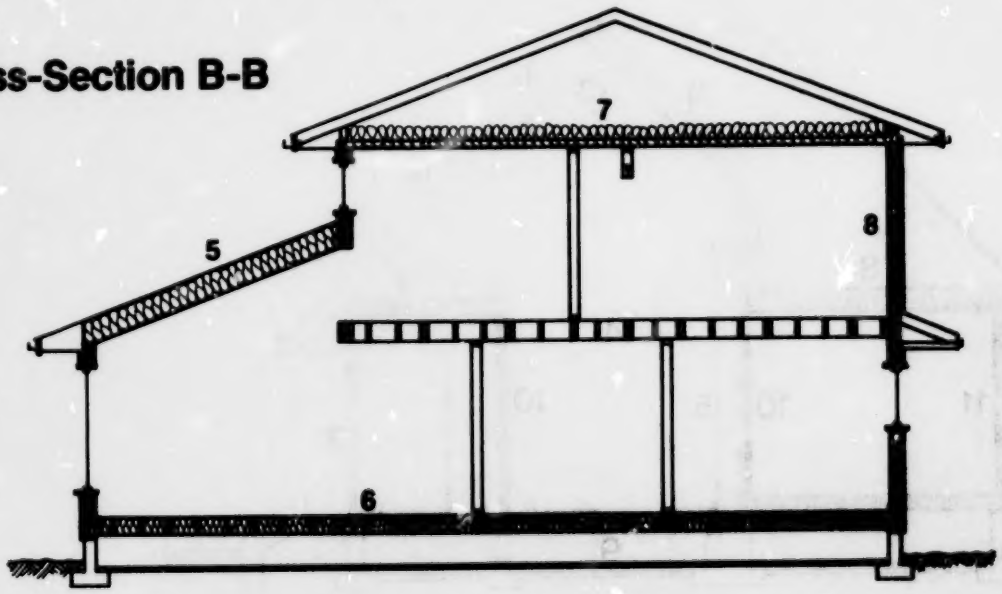
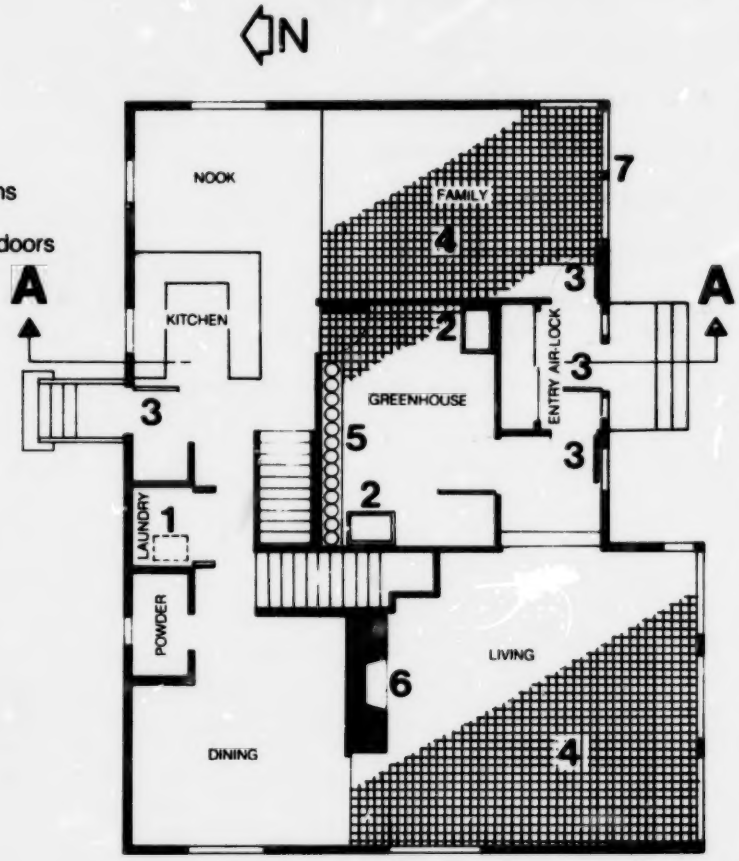


Figure 3

# Saanich Solar House

1. Air-to-air heat exchanger in crawl space
2. Greenhouse inlet floor vents
3. Metal insulated core doors
4. Clay tile floor for storing solar heat gains
5. Water storage cylinders for storing solar heat gains
6. Fireplace with outdoor combustion air and glass doors
7. Triple glazed windows
8. RSI-7 (R40) batt insulation
9. RSI-4.9 (R28) batt insulation
10. RSI-2.1 (R12) batt insulation
11. RSI-3.5 (R20) batt insulation
12. Greenhouse double glazing
13. Greenhouse exhaust fan
14. Greenhouse




## Main Floor Plan

## Cross Section A-A

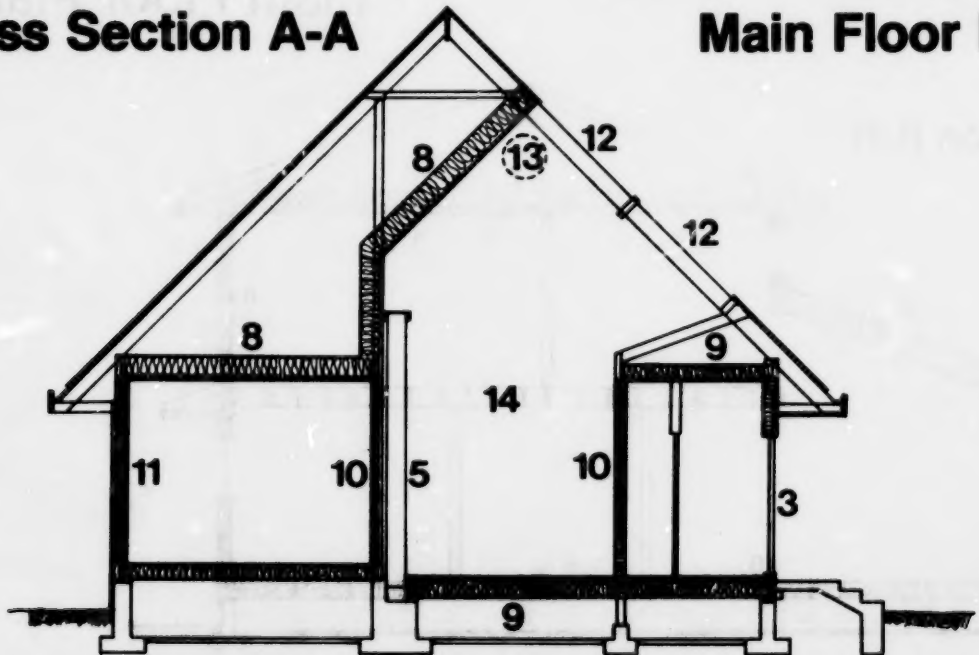
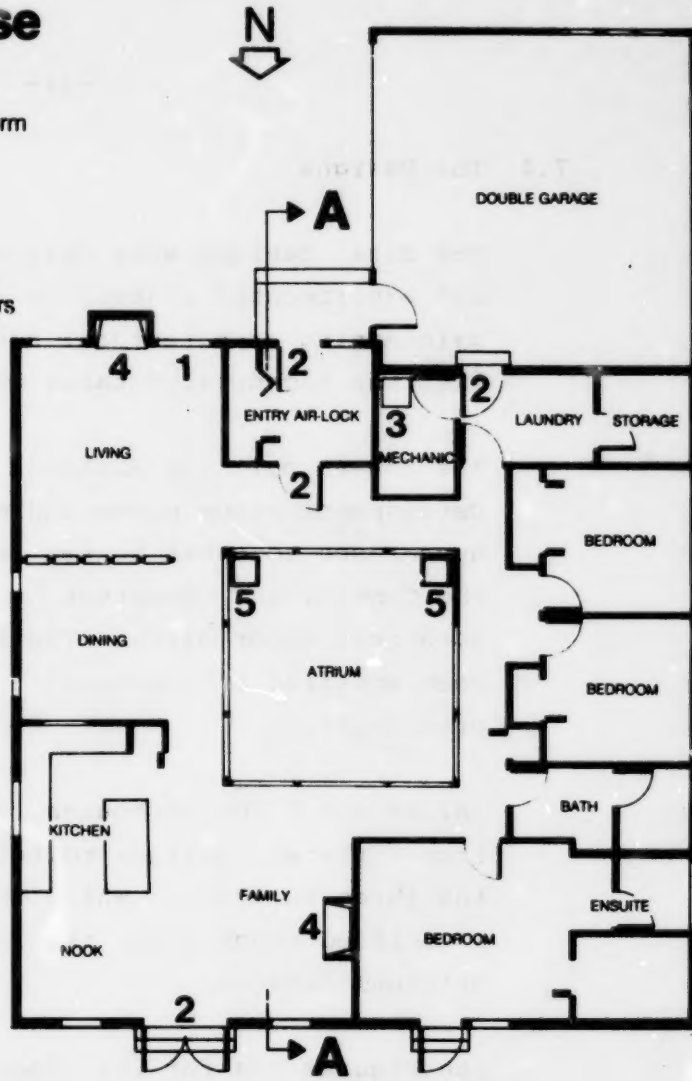


Figure 4

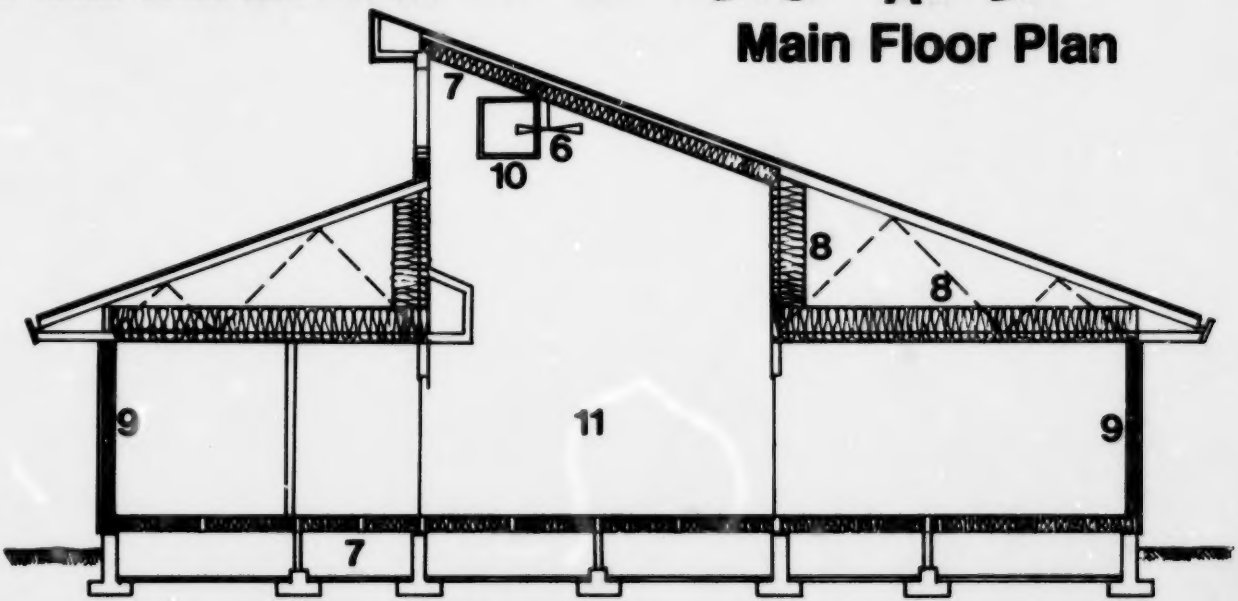
# Saanich Conserver House

1. Triple glazing — double glazed unit with interior storm windows
2. Metal insulated core doors
3. Air-to-air heat exchanger
4. Fireplace with outdoor combustion air and glass doors
5. Atrium floor inlet vents
6. Ceiling paddle fan
7. RSI-4.9 (R28) batt insulation
8. RSI-9.8 (R56) batt insulation
9. RSI-3.5 (R20) batt insulation with RSI-1.3 (R7.5) extruded polystyrene sheathing.
10. Atrium outlet vent
11. Atrium




## Main Floor Plan

## Cross-Section A-A



## 7.4 The Designs

The final designs were developed to meet demonstrational and experimental objectives and marketing concerns while maintaining architectural acceptability. Tables 1 and 2 list the technical details of each house.

The houses built in Richmond were derived from Nu-West Development stock plans and were very similar in appearance to other houses in the surrounding development. The Control and Conserver houses have essentially identical floor plans. The Solar house floor plan had been modified to accommodate passive solar design principles.

Unlike the Richmond houses, the Saanich houses originated from different designs to reflect preferences of each of the three builders. While the Conserver house design was a modified stock plan, the Control and Solar houses were original designs.

See Figures 1-4 for the floor plans and sections of each Solar and Conserver house.

## TABLE I - SAANICH HOUSES TECHNICAL DETAILS

| | SOLAR | CONSERVER |
|---|---|---|
| FLOOR AREA | 197 sq.m. | 187 sq.m. |
| WALLS | RSI 3.5 fibreglass batts between 38 x 140 mm studs 610 mm O.C. | RSI 3.5 fibreglass batts between 38 x 140 mm studs 610 mm O.C. RSI 1.3 extruded polystyrene sheathing |
| CEILING | RSI 7.0 fibreglass batts | RSI 9.8 fibreglass batts |
| FLOOR | RSI 4.9 fibreglass batts | RSI 4.9 fibreglass batts |
| WINDOWS | Triple glazed, Weatherstripped | Double glazed and inside storm Weatherstripped |
| DOORS | Steel insulated core RSI 2.1 Weatherstripped | Steel insulated core RSI 2.1 Weatherstripped |
| VENTILATION | Dehumidistat controlled Heat exchanger | Dehumidistat controlled Heat exchanger |
| HEATING SYSTEM | Electric forced air and bedroom baseboards Programmable thermostats | Electric forced air Programmable thermostats |
| ATRIUM | Double glazed | - |
| INFILTRATION | 6 mil poly air/vapour barrier caulked at seams | 6 mil poly air/ vapour barrier caulked at seams |
| THERMAL STORAGE | 1900 l water tubes and ceramic tile flooring | - |
| FIREPLACE | Outdoor combustion air and glass doors | Outdoor combustion air and glass doors |
| SOUTH GLAZING | $28m^2$, 14% of floor area | $8m^2$, 4% of floor area |

TABLE 2 - RICHMOND HOUSES TECHNICAL DETAILS

| | SOLAR | CONSERVER |
|---|---|---|
| FLOOR AREA | 211 sq.m. | 219 sq.m. |
| WALLS | RSI 2.1 fibreglass batts between 38 x 89 mm studs 406 mm O.C. RSI 1.2 rigid fibreglass sheating | RSI 3.5 fibreglass batts between 38 x 140 mm studs 610 mm O.C. RSI 1.2 rigid fibreglass sheathing |
| CEILING | RSI 7.0 fibreglass batts | RSI 7.0 fibreglass batts |
| FLOOR | RSI 4.9 fibreglass batts | RSI 1.7 extruded polystyrene under slab, RSI 1.3 extruded polysterene exterior of foundation wall |
| WINDOWS | South facing, double glazed, with night insulation, rest double glazed and inside storm, all weatherstripped | Double glazed and inside storm Weatherstripped |
| DOORS | Weatherstripped | Weatherstripped |
| VENTILATION | Dehumidistat controlled exhaust | Dehumidistat controlled heat exhchanger |
| HEATING SYSTEM | Gas condensing furnace within insulated mechanical room and bedroom electric base boards, programmable thermostat | Gas condensing furnace within insulated mechanical room and bedroom electric baseboards, programmable thermostat |
| GREENHOUSE | Double glazed | - |
| INFILTRATION | 6 mil poly air/vapour barrier caulked at seams | 6 mil poly air/ vapour barrier caulked at seams |
| THERMAL STORAGE | 1800 l water tubes and ceramic tile flooring | - |
| FIREPLACE | Outdoor combustion air and glass doors | Outdoor combustion air and glass doors |
| SOUTH GLAZING | $17m^2$, 12% of floor area | $9.3m^2$, 4% of floor area |

# 8. ECONOMIC ANALYSIS

## 8.1 Incremental Costs

Figures for incremental costs were available from two sources. As mentioned previously, a detailed estimate was done by an independent estimator prior to construction. As well, the builders provided estimates of what they considered to be incremental costs after construction was completed. Unfortunately, these estimates were derived from invoices from suppliers and subtrades and, therefore, it was not possible to accurately breakout costs for individual conservation measures. Another major problem in determining incremental costs was establishing what base case the comparison should made against. This was particularly troublesome in the Saanich Solar house as it was a custom design. In computing incremental costs for the house, the builder made the comparison with a house of similar size and quality but of standard design that he had constructed during the same period. The costs which were eventually used in the economic analysis were a combination of the estimate done prior to construction and the figures provided by the builder.

## 8.2 Savings Estimate for Each Measure

The computer program HOTCAN developed by NRC-Division of Building Research was used to calculate the energy savings of each conservation measure adopted.

The base case house was assumed to have essentially the same design as the corresponding low energy house but with lower insulation levels, higher infiltration rates, no mechanical ventilation or heat exchange, less south facing glazing in the comparison with the Solar houses and less efficient gas furnaces in the Richmond houses. In each comparison, the base case was assumed to have insulation levels of RSI 2.1 in the walls, RSI 3.5 in the ceiling, RSI 0.35 doors and double glazed windows.

The base case natural infiltration rate was assumed to be 0.6 air changes per hour derived from air tightness testing results of 20 new houses in the Vancouver area carried out by Solar Applications and Research Ltd. The average air change rate at 50 pascals was divided by 15 to estimate a natural air change rate. The 0.6 air change rate is also fairly consistent with CMHC figures.

The air change rate in each of the Low Energy Houses was assumed to be 0.5 air changes per hour as this is generally regarded at the minumum rate required to maintain acceptable air quality levels. The 0.5 air change rate is composed of natural infiltration and ventilation. The natural infiltration is derived by dividing air tightness test results of the Low Energy Houses at 50 pascals by a factor of 15. The remaining air change rate is assumed to be provided by the ventilation system.

Natural infiltration rates of 0.29 ACH (Richmond Solar) 0.31 ACH (Richmond Conserver), 0.31 ACH (Saanich Solar) and 0.27 ACH (Saanich Conserver) were used. The remaining

air change required to achieve the 0.5 air change rate was assumed to be provided by the dehumidistat fan in the Richmond Solar House and the heat exchanger in the remaining Low Energy Houses.

The current version of HOTCAN was not intended to handle slab-on-grade and crawlspace construction. To overcome the problem, several assumptions were made regarding its use.

In order to simulate the slab-on-grade Solar House very small values for basement above and below grade areas were input into the program. This, in effect, raises the HOTCAN basement floor to grade level, roughly simulating slab-on-grade construction.

Crawlspace construction found in the Richmond Conserver House and the Saanich Conserver and Solar Houses was more difficult to deal with. In the base case situation where the floor above the crawlspace is uninsulated, the floor area was treated in the program as a basement above grade wall area. Field measurements by Solar Applications and Research Ltd. have shown that the crawlspace temperature below an uninsulated floor is approximately midway between the main floor temperature and the ambient air temperature. Therefore, in order to simulate the temperature difference between the crawlspace and the main floor, the basement temperature setpoint in the HOTCAN run was assumed to be midway between the ambient air temperature and the main floor temperature. The average crawlspace temperature over the heating season was calculated to be 13.5$^{o}$C in Saanich and 13.6$^{o}$ in Richmond.

In the case of an insulated crawlspace, the crawlspace temperature was assumed to be the ambient air temperature since the crawlspace is vented. Therefore, the basement temperature in the HOTCAN runs were assumed equal to the mainfloor temperature.

Currently, HOTCAN assumes that the basement above grade temperature is the same as the main floor temperature. A modification of the program was necessary to enable the basement above grade area to be assigned a lower temperature than the main floor temperature.

## 8.3 Estimated Payback Periods

Based on the estimates of incremental cost and the resulting energy savings simple payback periods were calculated for each conservation measure. The energy savings, costs and payback periods are tabulated in Tables 3-6. In general, the Saanich houses have lower payback periods than the Richmond houses. This is due to the fact that the Saanich houses are electrically heated while the Richmond houses are assumed to be solely heated by natural gas. As a result, a higher cost energy source is being displaced in the Saanich houses. The assumption for the Richmond houses is not entirely true since the upper floors are electrically heated while only the lower floor is heated by natural gas. However, due to the fact that the Richmond houses could, in fact, have been entirely heated by natural gas and that the rationale for upper floor electrical baseboard was that it allowed for zone control, this assumption does not appear to unrealistically underestimate the total space heating cost for the Richmond houses.

Of the Low Energy Houses with crawlspace construction, insulating the floor above the crawlspace to RSI 4.9 results in the quickest payback periods ranging from 3-7 years depending on the house. The base case in this instance is an uninsulated floor above the crawlspace and typically one inch of extruded polystyrene along the exterior of the foundation walls.

Insulating the slab-on-grade floor of the Richmond Solar House, however, does not provide a very attractive payback. Heat loss occurs mainly along the slab perimeter and is relatively small through the slab centre area provided the water table is not high at this point. This fact combined with the high cost per R-value of the under slab rigid polystyrene resulted in a long payback of 31 years. However, the energy savings is likely to be greater than indicated by HOTCAN since water table levels are generally high in the Richmond area.

The next most cost-effective measure is increasing the insulation levels in the ceiling which ranges from a payback period of 6 years with the Saanich Solar house to 10 years with the Richmond Solar and Conserver houses.

Increasing the wall insulation level only appeared cost-effective in the Saanich Solar situation with an 8-year payback period. For the other houses, increasing the wall insulation level resulted in payback periods of 17 to 32 years. The principal reason for the high payback periods in these houses was the very high cost of rigid insulation sheathing, whether fibreglass or polystyrene when compared to solely fibreglass batt insulation used in the Saanich Solar house walls.

More highly insulated doors appeared to have a favourable payback period of 7-8 years in the case of the Saanich Conserver and Solar houses and only a marginal payback period of 18 years for the Richmond Solar and Conserver houses. Insulated doors in the Richmond houses have a poor payback period principally due to the displacement of lower cost natural gas.

The economics of reducing the air change rate and providing adequate ventilation to maintain acceptable air quality levels does not look very attractive. However, the long payback period belies the essential nature of controlling infiltration to prevent condensation and moisture problems and providing ventilation for the health and comfort of the occupants. Therefore, controlling the air change rate should be considered a necessity rather than an option in low energy housing.

The gas condensing furnaces in the Richmond houses cannot be considered cost-effective given the current premium compared to the cost of a standard furnace. However, greater acceptance of this product by the public and current research on reducing production costs will certainly narrow this premium so that gas condensing furnaces may become cost-effective in the future.

Means must be developed to significantly reduce the extra cost of providing thermal mass and distributing the collected solar energy before passive solar heating can become economically attractive. Even though only the cost of providing additional thermal mass and additional mechanical work were included in the payback calculation, the payback period was still very long. A homeowner would need to place a high enough value on the other benefits of passive solar heating such as natural lighting, view protection, etc., to overcome the poor economics of energy production. The economics could be improved through the use of lower levels of passive solar heating such as simple reorientation of the windows or through the use of lower cost materials.

Going from double to triple glazing also appears to be relatively unattractive economically. To achieve triple glazing in the Saanich Conserver house and the Richmond houses interior storm windows were added to double-glazed units. The Saanich Solar house was the only house to have triple glazing in a single unit. It would appear that the premium for triple glazing could be reduced through the mass production. At present, the high cost of triple glazing makes it uneconomical.

## TABLE 3

## RICHMOND SOLAR

### Economic Analysis - Individual Adoption of Conservation Measures

| | ENERGY USED/YR. ($) | (GJ) 70% eff. | ENERGY SAVED ($) | (GJ) | INCREMENTAL COST | SIMPLE PAYBACK (in yrs.) |
|---|---|---|---|---|---|---|
| BASE CASE | 318 | 78.6 | - | - | - | - |
| CEILING (RSI3.5 RSI4.9-7.0) | 294 | 72.9 | 24 | 5.7 | 240 | 10 |
| WALLS | 273 | 67.6 | 45 | 11.0 | 1420 | 32 |
| DOORS (RSI.35 RSI2.1) | 304 | 76 | 14 | 3 | 250 | 18 |
| FLOOR (uninsulated-RSI1.7) | 283 | 70.1 | 35 | 8.5 | 1090 | 31 |
| SOLAR (thermal mass & add'l. mech.) | 285 | 70.6 | 33 | 8.0 | 2690 | 82 |
| WINDOWS (N,E,W, double to triple) | 312 | 77.1 | 6 | 1.5 | 2160 | No Payback |
| WINDOWS (S, insulating shutter) | 311 | 77.0 | 7 | 1.6 | 600 | 86 |
| AIR CHANGE infil. reduction) & ventilation) | 292 | 50.6 | 26 | 28 | 820 | 32 |
| FURNACE (gas condensing 70%-90% eff.) | 247 | 42.8 | 71 | 35.8 | 1700 | 24 |
| AS DESIGNED | 87 | 21.5 | 231 | 57.1 | 10,370 | 45 |

TABLE 4

RICHMOND CONSERVER

Economic Analysis - Individual Adoption of Conservation Measures

| | ENERGY USED ($) | ENERGY USED (GJ) 70% eff. | ENERGY SAVED ($) | ENERGY SAVED (GJ) | INCREMENTAL COST | SIMPLE PAYBACK (in yrs.) |
|---|---|---|---|---|---|---|
| BASE CASE | 384 | 95 | - | - | - | - |
| CEILING (RSI3.5 RSI4.9-7.0) | 360 | 89 | 24 | 6 | 250 | 10 |
| WALLS (RSI2.1-RSI4.5) | 309 | 76 | 75 | 19 | 2218 | 30 |
| DOORS (RSI.35 RSI2.1) | 370 | 92 | 14 | 3 | 250 | 18 |
| FLOOR (uninsulated-RSI4.9) | 294 | 73 | 90 | 22 | 670 | 7 |
| WINDOWS (double to triple glazing) | 370 | 92 | 14 | 3 | 3890 | No payback |
| AIR CHANGE (infil. reduction & heat exchanger) | 323 | 80 | 61 | 15 | 2000 | 33 |
| FURNACE (gas condensing 70%-90% eff.) | 299 | 74 | 85 | 21 | 1700 | 20 |
| AS DESIGNED | 86 | 21 | 298 | 74 | 10,978 | 37 |

TABLE 5

SAANICH SOLAR

Economic Analysis - Individual Adoption of Conservation Measures

| | ENERGY USED ($) | ENERGY USED (GJ) 70% eff. | ENERGY SAVED ($) | ENERGY SAVED (GJ) | INCREMENTAL COST | SIMPLE PAYBACK (in yrs.) |
|---|---|---|---|---|---|---|
| BASE CASE | 799 | 72 | - | - | - | - |
| CEILING (RSI3.5 RSI7.0) | 728 | 66 | 71 | 1 | 440 | 6 |
| WALLS (RSI2.1-RSI3.5) | 709 | 64 | 90 | 8 | 730 | 8 |
| DOORS (RSI.35 RSI2.1) | 759 | 69 | 40 | 3 | 300 | 8 |
| FLOOR (uninsulated-RSI4.9) | 581 | 52 | 218 | 20 | 700 | 3 |
| SOLAR (thermal mass & add'l. mech.) | 734 | 66 | 65 | 6 | 4100 | 63 |
| WINDOWS (double to triple glazing) | 763 | 69 | 36 | 3 | 2370 | 65 |
| AIR CHANGE (infil. reduction & heat exchanger) | 683 | 61 | 116 | 11 | 2000 | 17 |
| AS DESIGNED | 195 | 18 | 604 | 54 | 10,644 | 18 |

TABLE 6

SAANICH CONSERVER

Economic Analysis - Individual Adoption of Conservation Measures

| | ENERGY USED ($) | ENERGY USED (GJ) | ENERGY SAVED ($) | ENERGY SAVED (GJ) | INCREMENTAL COST | SIMPLE PAYBACK (in yrs. |
|---|---|---|---|---|---|---|
| BASE CASE | 1106 | 99 | - | - | - | - |
| CEILING (RSI2.1 RS14.9-9.8) | 974 | 88 | 132 | 11 | 1150 | 9 |
| WALLS (RSI2.1-RSI4.7) | 955 | 86 | 151 | 13 | 2520 | 17 |
| DOORS (RSI.35 RSI2.1) | 1065 | 96 | 41 | 3 | 300 | 7 |
| FLOOR (uninsulated RSI4.9) | 788 | 71 | 318 | 28 | 1740 | 5 |
| WINDOWS (double to triple glazing) | 1079 | 97 | 27 | 2 | 2450 | 91 |
| AIR CHANGE (infil. reduction & heat exchanger) | 962 | 87 | 144 | 12 | 2000 | 14 |
| AS DESIGNED | 298 | 27 | 808 | 72 | 10160 | 13 |

## 9. Experience with Building Inspectors

No major problems were encountered with respect to acceptance of conservation measures by the building inspectors. However, instances did occur when inexperience in new technology caused some delays. In particular, the Gas Safety Inspector for the Richmond Conserver house did not approve the gas furnace installation because there was no flue. After being informed of the principle of the gas condensing furnace which requires no conventional vertical flue, the matter was resolved.

## 10. Experience with Builders

When interest among builders was being solicited, a fair amount of enthusiasm was generated. However, the number of builders actually willing to build varied from location to location.

The receptiveness of builders to energy conservation concepts and their willingness to build and sell something relatively new can be explained, to a large degree, by the residential building environment at the time.

The booming residential housing market in 1979 and 1980 reduced the potential risk of being innovative. As a result, many builders viewed low energy housing as a new potential growth market. Conversely, the same housing boom also kept many builders very busy which reduced the incentive to be innovative and did not allow builders to be as meticulous in construction as might have been the case with a more normal market. This situation was evident when the Saanich and Richmond houses were being built.

On the other hand, much of the difficulty experienced in trying to have low energy houses built in Prince George resulted from the dismal housing market which followed the housing boom. The chosen builder was reluctant to build until the market improved and had fairly rigid requirements for a design he thought to be marketable.

The selected builders were inexperienced in the techniques that they were being asked to use. Although, this was known, it was felt that with sufficient training the job could be carried out adequately. A fair amount of time was spent with the builders explaining the techniques required. Unfortunately, this training did not filter down to the crews actually doing the work. The lesson learned from this is the need for an on-site training dealing directly with the crew doing the work.

An inexperienced builder subtrade also results in unrealistic bids since the complexity of the job is not fully appreciated. This is particularly so with the air/vapour barrier. As a result, the job is likely to be given to the lowest bidder who has fallen into this trap. Since the job has been under bid, there is little incentive to spend the time and care required. This has resulted in poor coordination of the air/vapour barrier installation with other subtrades. In some instances, poly was not installed before the fireplace and bathtub were put into place which made subsequent poly installation very difficult.

The poor transfer of information from the builder to the subtrades was exacerbated in the Richmond case by the fact that the construction supervisor position changed hands approximately five times from start to finish of the houses.

Although builder inexperience and the economic climate resulted in a number of problems (which were generally not of the builder's making) the builders were generally cooperative and receptive to trying innovative energy conservation techniques.

## 11. Montoring

Monitoring of the energy consumption of the low energy houses was carried out by Solar Applications and Research Ltd. The monitoring report produced by Solar Applications and Research Ltd. is found in Appendix A.

Direct comparison of actual energy use by each house was not possible due to several factors. The monitoring indicated quite widely varying conditions from one house to another including the number of occupants, hot water usage, lighting and appliance usage, the indoor setpoints, and the amount of use of fireplaces and wood stoves.

The monitoring period was not consistent for each house since the houses were required to be sold and occupied before monitoring could proceed. In fact, at the time of writing this report, the Saanich Conserver house was still unsold. Therefore, no usable data had been recorded for this house.

However, by standardizing the conditions of the Richmond houses for which adequate data was available to allow a valid heat loss coefficient calculation, long term predictions were possible. These predictions indicated that the Solar and Conserver houses will use 59% and 66% less energy than the Control house.

## 12. THE MARKETING EXPERIENCE

When the houses were completed and placed on the market, sales of these houses were rather slow. This was surprising in view of the fact that the houses were highly publicized and promised to offer the buyer $10,000 worth of conservation features free. However, all houses have now been sold except for the Saanich Conserver house. Table 7 lists the initial asking price, the final asking price and the final selling price.

## TABLE 7 - LOW ENERGY HOUSE PRICES

| | Initial Asking Price | Final Asking Price | Selling Price |
|---|---|---|---|
| **Richmond** | | | |
| Solar | $215,000 (Mar.'82) | $154,000 (Oct.'82) | $140,000 (Oct,'82) |
| Conserver | 205,000 (Mar.'82) | $149,000 (Nov.'82) | $135,000 (Nov.'82) |
| **Saanich** | | | |
| Solar | $185,000 (Nov.'81) | $145,000 (Nov.'82) | $140,000 (Nov.'82) |
| Conserver | $189,000 (Nov.'81) | $149,000 (Sept.'83) | UNSOLD (Sept.'83) |

The comments in Table 8 were elicited from the builders and realtors of the houses as possible reasons for the slow sales.

TABLE 8 - COMMENTS FROM REALTORS AND BUILDERS

| | SAANICH | | RICHMOND | |
|---|---|---|---|---|
| | Solar | Conserver | Solar | Conserver |
| 1. No dining room | - | - | X | - |
| 2. Cramped laundry room under stairwell | - | - | X | X |
| 3. Small third bedroom | - | - | X | X |
| 4. Re-circulating rather than vented range hood | - | - | X | X |
| 5. Resistance to new concepts such as passive solar heating, air-to-air heat exchangers, gas-condensing furnaces, etc. | - | - | X | X |
| 6. Type of individual attracted to solar would rather build himself | X | - | - | - |
| 7. Air lock vestibule awkward to enter & exit | | | | |
| 8. Resistance to high initial price | X | X | X | X |
| 9. Consumers not willing to pay full cost of conservation features | X | X | X | X |
| 10. Poor market primarily responsible for slow sales | X | X | X | X |
| 11. Too many stairs to front porch and bedrooms | X | - | - | - |
| 12. North side poor location for sundeck | X | - | - | - |
| 13. Strange appearance | X | - | - | - |

To draw some general conclusions to account for the slow house sales, the following is offered.

1. The roller coaster housing market of the past few years has been the primary reason for the slow sales of these houses. Up to 1981, the B.C. market seemed to be insatiable which led to the construction of larger and more expensive houses. The Low Energy Houses were built under this environment. However, at the time these houses were being completed and placed on the market, interest rates went sky rocketing resulting in a dramatic decline in the housing market. The emphasis in the market moved towards more affordable housing which were smaller and less expensive. The Low Energy Houses were competing in a market where there was very little overall demand and were out of step with the emphasis towards more affordable housing.

2. The general public does not place a very high value on energy conservation in the home which resulted in resistance to paying the extra cost required for the conservation measures employed. To the general public, the benefits of energy conservation is not apparent.

3. The houses were eventually able to be sold (with exception of the Saanich Conserver house) due to slowly improving market conditions and also as a result of pricing which no longer reflected the added cost of the energy conservation measures.

COMMENTS BY BUILDERS

The builders were asked to comment on how the houses might have been improved upon. The opinions and views of the builders are presented in the following:

RICHMOND

Conserver:- The additional door in the entrance is good in theory, however, due to the small area between the two doors, the second door is probably going to be left open.

- The forced air system used is very expensive, in relation to its benefits.

Solar: - The forced air system is very expensive, in relation to its benefits.

- Serious consideration must be given to the following items due to lack of competition in availability of product;

1. Gas condensing heating system
2. Insulating shutters
3. Heat storage tanks in solarium

- A replacement system should be found for the tiled area as this is of great expense. Possibly a lino type flooring that would have the same effect as the tile might be substituted.

SAANICH:

Conserver: - Although the electric forced-air heating system was installed because it allowed conversion to natural gas if/when it becomes available to Vancouver Island and because it was able to provide a ducting system which was also required by the air-to-air heat exchanger, it was felt that electric baseboard heat could have been installed at considerably less expense.

- Crawlspace construction was chosen because it allowed the floor to be insulated to a higher degree with relatively inexpensive batt insulation and allowed space for insulated duct runs. However, slab-on-grade construction would have been much less expensive without the need for extra flooring and framing required in crawlspace construction.

- The smaller odd-sized windows required for the house were actually more expensive than larger standard sized windows.

- Custom made trusses were required to provide enough clearance above the exterior walls for RSI9.8 batt insulation. Standard trusses would have been less costly and would have had little effect on the overall R-value of the ceiling.

Solar:

- A design which did not have such a steeply pitched roof requiring custom trusses would have been less expensive. The steeply pitched roof also contributed to higher roofing costs due to the increased roof area.

- Similarly with the Conserver house, slab-on-grade rather than crawlspace construction would have been less expensive.

- Use of electric baseboard rather than forced-air electric heat would have reduced costs. The rationale for using forced-air electric heat is the same as that for the Conserver house.

- Little benefit was thought to be gained by the use of an air-lock vestibule while the cost was relatively high.

- The high cost of the solarium makes its justification difficult.

## 14. ECONOMIC IMPACT

The principles and techniques demonstrated in this project certainly have the potential to be adopted on an industry-wide scale. This includes not only the new residential construction industry, but also the existing housing retrofit and renovation industry and, in fact, in any building application where space heating costs are of a concern.

Higher insulation levels, window orientation to maximize solar gain and reduced infiltration levels are conservation principles which have been generally recognized in the new housing industry. The level of adoption varies from builder to builder and from region to region. Generally speaking, the level of adoption is qreater where space heating costs are high such as in the northern towns (an example is Dawson Creek). In more mild climates such as the Lower Mainland, high cost-effective levels of adoption have not generally penetrated the mass housing market. This indicates a significant potential to reduce energy consumption levels in new housing in these areas. It appears that the level of adoption is more a function of market demand rather than market supply. In low level adoption areas, people, in general, are not willing to accept the higher cost of conservation even though the capability in the industry exists.

The low energy housing industry has spawned the development of different products and new skills. New and improved products include air-to-air heat exchangers, new insulations for different applications, new caulking and sealing compounds, more efficient furnaces and improved window and door construction. The new skills required are energy conservation design skills and construction trade skills required for the proper installation of air/vapour barriers, the application of the various insulation types, the handling of the new glazings and the installation of new heating and ventilation equipment.

In general, cost-effective adoption of the measures demonstrated in this project will increase employment through the production of new products and the requirement for new skills and will raise the general level of wealth. People will be spending less to heat their homes leaving a larger share of their income for discretionary expenditures.

The impact of this particular project on the industry is difficult to ascertain although it certainly would be judged to be positive.

APPENDIX A

For the B.C. Ministry of Energy, Mines and Petroleum Resources.

# B.C. LOW ENERGY DEMONSTRATION HOUSES

# FINAL MONITORING REPORT 1982-1983

by Ken Cooper

July, 1983

SOLAR
Solar Applications & Research Ltd.

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**SUMMARY**

Monitoring was carried out for 1982/83 in two B.C. Ministry of Energy, Mines and Petroleum Resources low energy demonstration homes and one control home in each of two locations - Richmond and Saanich. The purpose of the monitoring was to enable a comparison of two low energy building types, both with each other and with the control.

Due to the fact that the homes were not occupied for the full period (see Summary Table), analysis of data and results presented here are for less than the full monitored period. Unoccupied houses, in some cases with no heat on, do not yield results that are meaningful for a space heating analysis.

| House | Occupancy Date | Period of Monitored Results | Heated Floor Area $m^2$ | Building HLC (W/C) | Inside Temp (C) | Total Load (GJ) | Int. Gains (GJ) | Solar Gains (GJ) | Fuel (GJ) |
|---|---|---|---|---|---|---|---|---|---|
| **Richmond** | | | | | | | | | |
| Control | 12 Aug 82 | 5 Nov 82 to 29 Apr 83 | 219 | 340 | 19.6 | 68.9 | 20.2 | 9.6 | 57.1 |
| Solar | 15 Oct 82 | " | 211 | 256 | 20.4 | 54.9 | 19.7 | 13.6 | 23.2 |
| Conserver | 2 Nov 82 | " | 219 | 200 | 23.0 | 50.6 | 15.0 | 6.6 | 31.4 |
| **Saanich** | | | | | | | | | |
| Control | 29 Apr 82 | 7 Jan 83 to 15 Apr 83 | 187 | 359 | 21.1 | 42.4 | 10.9 | 26.1* | 5.4** |
| Solar | 3 Jan 83 | " | 197 | 312 | 20.4 | 35.2 | 10.4 | 9.0 | 16.6 |
| Conserver | unoccupied | - | 187 | - | - | - | - | - | - |

Note that house to house comparison of energy values is not possible due to widely varying operating conditions of inside temperature and internal gains. Also, the energy values for the Saanich houses are for a shorter period than for the Richmond houses due to the Saanich Solar house being unoccupied until January 1983.

Long term predicted annual fuel consumption for the Richmond Control, Solar and Conserver houses was 117 GJ, 48 GJ and 40 GJ, respectively. This corresponds to 131, 56 and 45 kJ/$m^2$ floor area Degree Day Celsius (21C base), respectively.***

* Including approximately 20 GJ (est.) of uncontrolled wood heat.

** Plus about 40 GJ (est.) of supplied wood energy.

*** All with inside temperature of 21°C and internal gains of 1000W.

## 1.0 PROJECT DESCRIPTION

The B.C. Ministry of Energy, Mines and Petroleum Resources provided funds for the incremental cost of two low energy demonstration homes in each of two locations - Richmond and Saanich Peninsula on Vancouver Island. At each location, there is also a third home that is conventional in construction which was intended to serve as a control. The two low energy houses at each location demonstrate two approaches to reduced space heating consumption. One emphasizes conservation while the other emphasizes passive solar techniques.

The Saanich Control house used atypically high wall insulation values and south glazed areas.

Features are described in Tables 1 and 2.

TABLE 1

Richmond Houses - Description

| | Control | Passive Solar | Conserver |
|---|---|---|---|
| Heated Floor Area ($m^2$) | 219 | 211 | 219 |
| Walls | RSI 2.1 | RSI 3.3 | RSI 4.2 |
| Ceiling | RSI 3.5 | RSI 7.0 | RSI 7.0 |
| Floor | RSI 0.6 slab edge insulation | RSI 1.8 slab | RSI 4.9 crawlspace |
| Windows | Double | Double south*, rest triple | Triple |
| Infiltration | Normal | Caulked air barrier | Caulked air barrier |
| Ventilation | Bath and kitchen fans | Humidistat controlled ventilation | Heat exchanger |
| Heating System | Normal gas | Condensing gas | Condensing gas |
| | - plus electric baseboard upstairs - | | |
| Fireplaces | | | |
| - Type | Conventional | Doors and outdoor combustion air | Doors and outdoor combustion air |
| - Number | Two | One | Two |
| South Windows ($m^2$) | 9.3 | 13.0 | 9.3 |
| % of floor area | 4 | 6 | 4 |
| Solarium: | No | Yes | No |
| South Glazing ($m^2$) | | 14 | |
| Thermal Storage | | 1800L water | |

* With manually operated night insulation.

TABLE 2

Saanich Houses - Description

| | Control | Passive Solar | Conserver |
|---|---|---|---|
| Heated Floor Area ($m^2$) | 187 | 197 | 187 |
| Walls | RSI 3.0 | RSI 3.0 | RSI 4.3 |
| Ceiling | RSI 4.9 | RSI 7.0 | RSI 9.8 |
| Floor | No insulation | RSI 4.9 | RSI 4.9 |
| Windows | Double | Triple | Triple |
| Infiltration | Normal | Caulked air barrier | Caulked air barrier |
| Ventilation | Bath and kitchen fans | Heat exchanger | Heat exchanger |
| Heating System | Electric baseboard | Electric forced air Baseboard upstairs | Electric forced air |
| Fireplaces | | | |
| - Type | Conventional + wood stove | Doors and outdoor combustion air | Doors and outdoor combustion air |
| - Number | One each | One | Two |
| South Windows ($m^2$) | 14 | 16 | 8 |
| % of floor area | 7 | 8 | 4 |
| Solarium: | No | Yes | Yes |
| Double glazed ($m^2$) | | 12 | 4.5 |
| Thermal Storage | | 1900L water | Stucco only |

## 2.0 MONITORING PROCEDURES

Because passsive solar systems are structurally and thermally integrated into the building envelope, it was not feasible to measure the solar contribution directly. Instead, it was determined by calculation of the total space heating load and its supply components (Appendix C). The major components, electrical auxiliary, gas auxiliary, hot water and utilities were measured. The usable space heating portion of utilities, hot water and gas auxiliary were estimated, however.

Monitoring to determine the hourly average inside temperatures in each house was carried out by a Campbell Scientific CR21 data logger. Outside temperatures were monitored by the Conserver house data logger at each location. All temperatures were monitored using Fenwall UUT51J1 matched curve non-linear thermistors with linearization taking place in the data logger. Horizontal insolation was summed over each hour by the data logger in the solar house, using a Licor photovoltaic pyranometer.

Energy consumption was read approximately weekly from accumulating electrical and gas meters. Sub-metering was installed on hot water and space heating. Utilities consumption was determined by subtraction of sub-metered quantities from total consumption.

In order to carry out an energy balance, the building heat loss coefficient (HLC) was determined by regression of the sum of all non-solar space heating energy versus actual degree days for daily and weekly periods with minimal solar input.

Total space heating load was determined by multiplying the heat loss coefficient by the measured inside to outside temperature difference. The solar contribution for each period was then determined by subtracting non-solar gains - utilities, hot water, people and auxiliary - from the total space heating load.

De-pressurization tests to determine envelope airtightness were carried out by SOLAR Applications and Research Ltd., as well as by Aastro Insulation*.

* Under separate contract to the Ministry of Energy, Mines and Petroleum Resources.

## 3.0 RESULTS

### 3.1 Operational Comments

The six houses were sold and occupied at various times by families of different size (Table 3). As little or no control could be maintained over lifestyle, the manner in which the five families in the occupied houses operated their homes varied considerably.

TABLE 3

| House | Occupancy Date | Family Statistics | | | |
|---|---|---|---|---|---|
| | | Adults | Teens | Children | Total |
| **Richmond** | | | | | |
| Control | 12 August 1982 | 2 | 2 | 1 | 5 |
| Solar | 15 October 1982 | 2 | 1 | 0 | 3 |
| Conserver | 2 November 1982 | 2 | 0 | 1 | 3 |
| **Saanich** | | | | | |
| Control | 29 April 1982 | 2 | 2 | 1 | 5 |
| Solar | 3 January 1983 | 2 | 0 | 3 | 5 |
| Conserver | Unoccupied | 0 | 0 | 0 | 0 |

The houses had various wood-burning appliances which were generally not used to a significant degree - with the exception of the Saanich Control house (Table 4).

Inside temperatures, water and utilities energy use also varied widely (Table 5).

TABLE 4

| House | Wood Appliances | Use |
|---|---|---|
| Richmond | | |
| Control | 2 conventional fireplaces | Less than once per week |
| Solar | 1 fireplace* | About 8 times total |
| Conserver | 2 fireplaces* | Not used |
| Saanich | | |
| Control | 1 heatilator fireplace | Not used |
| | 1 wood stove | Used 2 to 3 nights per week |
| Solar | 1 fireplace* | About 4 times total |
| Conserver | 2 fireplaces* | - |

TABLE 5

| House | Inside Temperature (C) | Water Demand (MJ/day) | Utilities (MJ/day) | Usable Internal Gains** (MJ/day) |
|---|---|---|---|---|
| Richmond*** | | | | |
| Control | 19.6 | 107 | 91 | 116 |
| Solar | 20.3 | 45 | 106 | 113 |
| Conserver | 23.0 | 60 | 68 | 86 |
| Saanich**** | | | | |
| Control | 21.1 | 86 | 89 | 111 |
| Solar | 20.4 | 62 | 80 | 106 |
| Conserver | - | - | - | - |

* With tight glass doors and a combustion air supply.

** Usable gains for space heating equals 15% of water demand plus people gains plus 90 - 95% of utilities.

*** For November 5, 1982 through April 29, 1983.

**** For January 7, 1983 through April 15, 1983.

Because the Saanich Conserver house was unoccupied and, for most of the monitored period, unheated, there was no useful data for this house. Data for the Saanich Control house was presented and analyzed for the period during which the Saanich Solar house was occupied. However, due to the frequent use of the wood stove in the Saanich control house, energy balances for it are likely to be so inaccurate as to render it virtually useless as a control.

## 3.2 Analysis of Monitoring Data and Methods

The lack of a full year of monitored results for occupied houses is a severe limitation on the results. For example, the Saanich Solar house was occupied and monitored from January 7, 1983 to April 15, 1983. Its heat was turned off for most of October, November and December so no useful data is available for that period. Data for the Richmond houses is more complete, as only the early fall and late spring are missing. Summer data for comfort analysis is also unavailable for all the houses while occupied.

During the occupied periods, hourly temperature and weekly energy data is essentially complete for the Richmond houses. In Saanich, however, access to the unoccupied Conserver house was severely limited, with the result that most of the outside temperature data is missing. Therefore, outside temperature data for Victoria International Airport was used for the Saanich houses. In addition, short periods of inside temperature data are unavailable for the Saanich houses, for February and March of 1983, due to low tape recorder batteries. This should not be critical to the analysis, however, as average inside temperatures show very little variation week to week. The Saanich pyranometer began to show a significant drift in output (strongly negative at night) early in 1983, so insolation data for the spring is unreliable. Since insolation data is not used in the energy balance, this is not critical.

Because the measured energy use is based on accumulating meters, this data is available for the entire period for all houses. Thus, for example, a comparison of auxiliary energy use is possible for any common period. <u>However</u>, valid comparisons require all operational factors to be identical. As conditions of occupancy (temperature, internal gains, etc. - Section 3.1) are not the same, house to house comparison using monitored data is <u>not</u> possible.

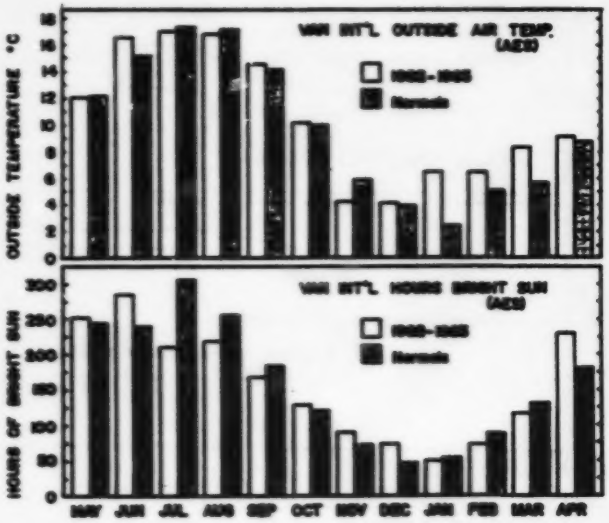
The monitored data can be used, however, to determine the building Heat Loss Coefficient (Section 3.5) and conditions of operation, which can be used in performance algorithms to predict energy balances under a standard set of conditions (Appendix A).

### 3.3 Meteorological Comparisons

Most of the monitored period, particularly in the spring of 1983, was significantly warmer than the long term (Fig. 1), resulting in less than average consumption. Insolation, as represented by hours of bright sun (Fig. 1) was closer to average - slightly more than average in the fall and slightly less than average in the spring.

Richmond site measured temperatures were typically within plus or minus 1°C of those at Vancouver International Airport. Richmond site measured insolation (Licor pyranometer) was 6% to 10% low compared to the average of horizontal insolation measured at Vancouver International and Tsawwassen Ferry*. As the difference was quite consistent, it is likely that the Licor pyranometer is reading about 8% low.

FIGURE 1




* Measured with calibrated Kipp and Zonan pyranometers.
Data supplied by Dr. John Hay of UBC Dept. of Geography.

### 3.4 Comfort Aspects

The occupants of all the houses judged their homes to be comfortable, though none of them have lived in their homes for a full year. The only overheating observed during the monitored period was in the Saanich Control house and was primarily due to the over-sized wood stove located on the main floor and the lack of an air circulation system (electric baseboard heating). Clear day temperature swings for the other houses were within acceptable limits (Figs. 2 and 3).

FIGURE 2

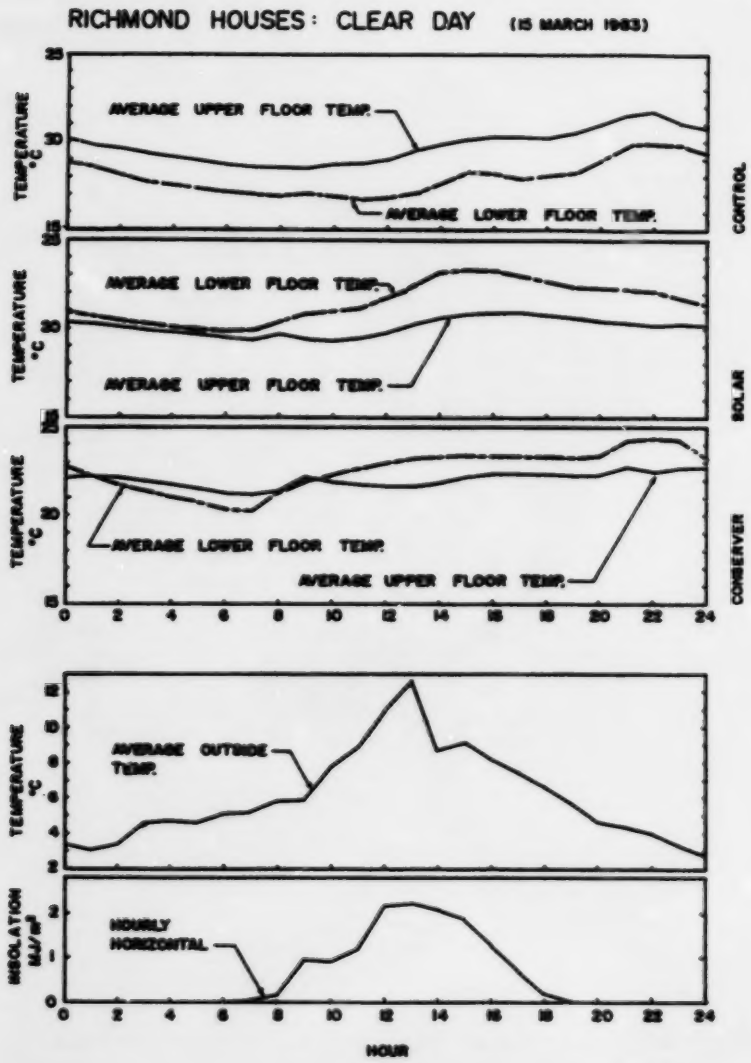
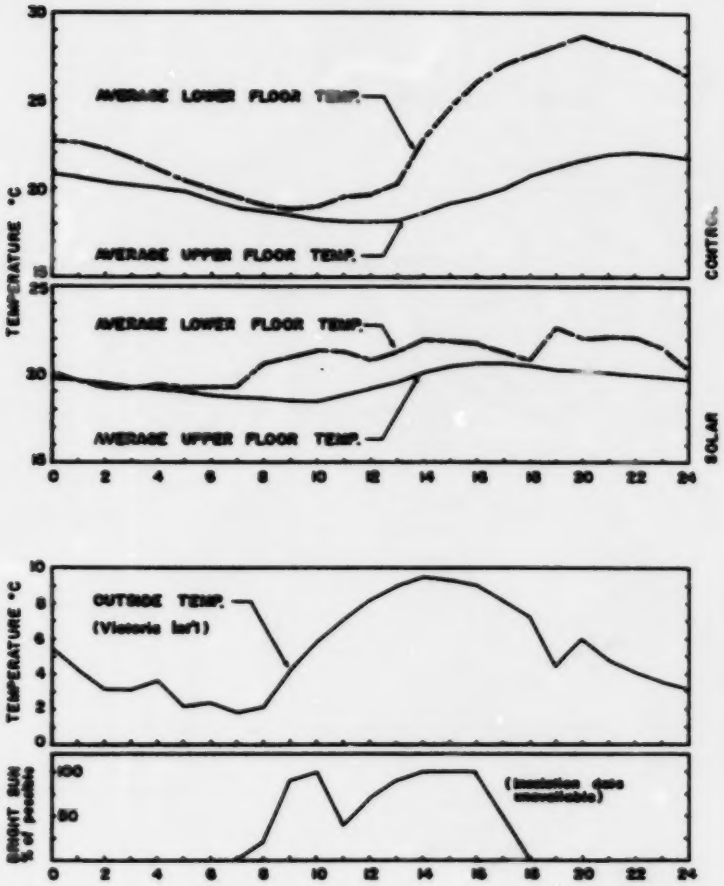


FIGURE 3

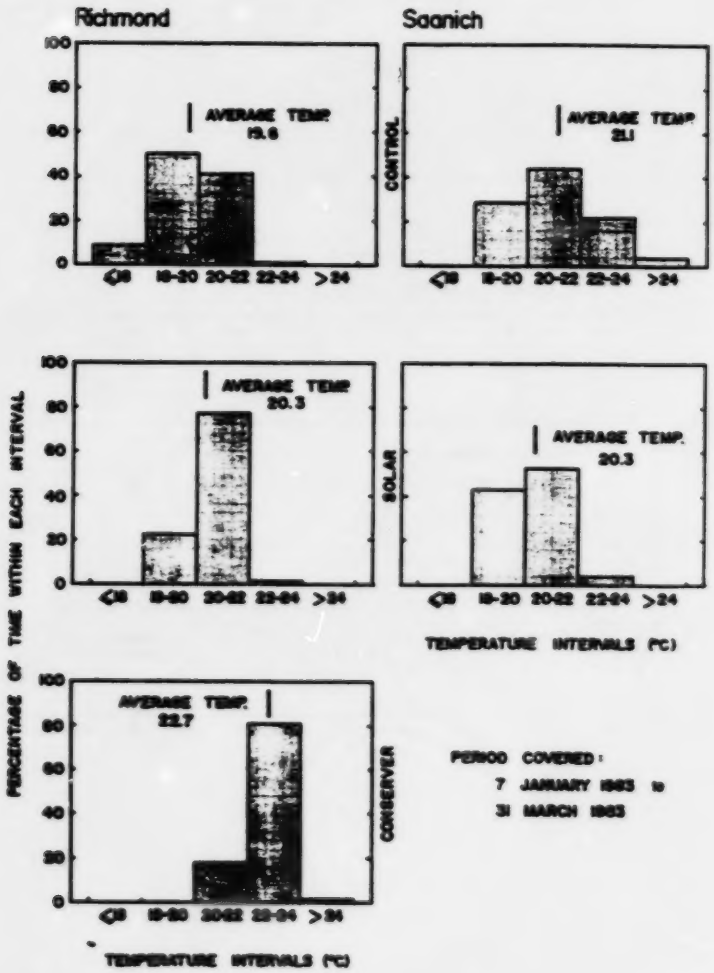
SAANICH HOUSES : CLEAR DAY (27 FEBRUARY 1983)



The time distribution of inside temperatures shows significant differences of perceived comfortable conditions (Fig. 4), even when the average temperature was the same (compare Richmond and Saanich Solar houses).

FIGURE 4

INSIDE TEMPERATURE/TIME DISTRIBUTION



## 3.5 Short term tests

### 3.5.1 De-pressurization Tests

Fan de-pressurization tests were carried out by SOLAR Applications and Research Ltd. and Aastro Insulation. The results (Table 6) show significant changes with:

a) remedial work
b) after gyproc applied
c) different testers

Typically, natural air change rates are about one twentieth the 50 Pascal rate.

Based on the Aastro Insulation tests, two control houses are significantly more airtight than is typical of new housing in the Lower Mainland****.

The airtightness of the houses did not achieve expectations for the following reasons:

a) Lack of design control which resulted in overhangs, interior garages and other hard to seal features.
b) Lack of control by construction foremen (three foremen on the Richmond Solar).
c) Lack of crew experience.

The large differences between before and after gyproc are likely due to inconsistent test procedures.

TABLE 6

Fan De-pressurization Results

| House | Air changes per house at 50 Pascals* | | |
|---|---|---|---|
| | House as is | House sealed** Before gyproc | After gyproc |
| **Richmond** | | | |
| Control | - | - | 4.6 to 4.4*** |
| Solar | 5.5 (SAR) | 14.4 to 11.8*** | 2.1 4.4 (SAR) |
| Conserver | 5.6 (SAR) | 7.6 to 6.5*** | 2.3 4.6 (SAR) |
| **Saanich** | | | |
| Control | - | - | 5.7 |
| Solar | - | 5.4 to 3.2*** | 4.6 |
| Conserver | - | 7.2 to 4.7*** | 4.8 |

* House air changes per hour at 50 Pascals house to outside pressure differential.
** Intentional vents and flues sealed.
*** Second value after remedial air sealing.
**** "Airtightness Tests of 20 Houses in the Greater Vancouver Area", SOLAR Applications and Research Ltd. contract for SBC 1982. The 50 Pascal air change rate averaged 9.3 and ranged from 6.1 to 12.3.

### 3.5.2 House Heat Loss Coefficients

House heat loss coefficients were determined by a regression curve fitting of non-solar gains and actual degree days for periods with minimal solar (Table 7). Both daily and weekly periods were used to maximize the number of points used in the analysis and to ensure that short term storage effects were minimized. Ideally, controlled conditions of temperature, occupancy and insolation would result in minimal scatter, however real, occupant controlled, conditions result in some scatter.

The heat exchanger in the Richmond Conserver house operated on low speed the majority of the time. Over the occupied period, it operated on high speed less than 10% of the time for all but five weeks. During those five weeks, the heat exchanger was on high speed for between 10% and 20% of the time. There was no consistent correlation between heat exchanger high speed operating time and Heat Loss Coefficient. The heat exchanger in the Saanich Solar home operated on high speed less than 10% of the time.

TABLE 7

Heat Loss Coefficients (see Appendix B)

| House | HLC (W/C) | Correlation Coefficient |
|---|---|---|
| **Richmond** | | |
| Control | 340 | 0.983 |
| Solar | 256 | 0.9996 |
| Conserver | 200 | 0.986 |
| **Saanich** | | |
| Control | 359* | -* |
| Solar | 312 | 0.998 |
| Conserver | -** | - |

* HLC for the Saanich Control house determined from seven single day tests, prior to ocupancy, with some missing inside temperature data. Values prior to occupancy had to be used due to uncontrolled wood consumption after occupancy. Due to the limited range of degree days, the HLC was estimated by simple division of non-solar gains by degree days. This value is, therefore, not likely to be as accurate.

** HLC for the Saanich Conserver house was not determined as the only winter period with heat in the house also had large consumption by the hot tub in the unheated atrium.

### 3.6 Energy Balances

Energy balances were carried out for five of the six houses for periods of common occupancy - November 5, 1982 to April 29, 1983 for the Richmond houses (Tables 9, 10 and 11) and January 7, 1983 to April 15, 1983 for the Saanich houses (Tables 12 and 13). The calculated solar contribution depends strongly on the accuracy of determination of total load and non-solar gains as it is generally a small difference between two large values. An error of 5% to 10% in HLC, for example, can change the calculated solar contribution by as much as 50%. This possible error is particularly significant in houses with a small solar fraction.

The negative values of solar are due to errors in the HLC and to storage effects* due to changes in inside temperature from week to week. The gross percentage solar shown is based on solar to total load. Some sources quote the solar fraction based on net load (total load minus internal gains) as shown in Table 8.

TABLE 8

| House | % Solar (January 7 - April 15, 83) | |
|---|---|---|
| | Gross | Net |
| **Richmond** | | |
| Control | 15 | 22 |
| Solar | 24 | 39 |
| Conserver | 17 | 24 |
| **Saanich** | | |
| Control | -** | -** |
| Solar | 26 | 36 |

* The energy balances assume steady state conditions with no energy storage carry over to following weeks. If the temperature in the house changes from one week to the next, energy will be drawn from, or put into, the thermal storage in the building.

** Saanich Control not included due to the fact that wood heat supplied had to be combined with solar, and it is therefore not comparable.

TABLE 9

RICHMOND CONTROL HOUSE ENERGY BALANCE
Occupied period

HLC (W/C) = 340 Furnace Eff. = .65

| PERIOD ENDING | DAYS IN PERIOD | INSIDE TEMP. (C) | OUTSIDE TEMP. (C) | DEGREE DAYS (DDC) | PEOPLE (MJ) | WATER DEMAND (MJ) | UTILITY (MJ) | INT. GAINS (MJ) | SPACE GAS (MJ) | SPACE ELECT. (MJ) | NON-SOL GAINS (MJ) | TOTAL LOAD (MJ) | SOLAR (MJ) | SOLAR (%) | BRIGHT SUN (hrs) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NOV 19 | 14 | 19.50 | 4.20 | 214 | 252 | 1663 | 1337 | 1705 | 4923 | 390 | 5295 | 6292 | 998 | 16 | 52 |
| 26 | 7 | 19.00 | 0.20 | 132 | 126 | 760 | 606 | 785 | 3262 | 306 | 3212 | 3866 | 654 | 17 | 27 |
| DEC 3 | 7 | 19.40 | 7.80 | 87 | 126 | 773 | 637 | 815 | 1756 | 180 | 2137 | 2550 | 413 | 16 | 2 |
| 10 | 7 | 19.70 | 3.00 | 117 | 126 | 832 | 375 | 588 | 2747 | 259 | 2633 | 3434 | 801 | 23 | 31 |
| 17 | 7 | 19.70 | 6.40 | 93 | 126 | 888 | 713 | 889 | 2607 | 239 | 2832 | 2735 | -88 | -3 | 3 |
| 24 | 7 | 19.70 | 5.40 | 100 | 126 | 744 | 729 | 894 | 2909 | 237 | 3022 | 2941 | -81 | -3 | 11 |
| 31 | 7 | 19.60 | 1.10 | 130 | 126 | 729 | 907 | 1052 | 3193 | 259 | 3386 | 3804 | 418 | 11 | 25 |
| JAN 7 | 7 | 19.50 | 5.30 | 99 | 126 | 727 | 1082 | 1209 | 2341 | 216 | 2947 | 2920 | -27 | -1 | 4 |
| 14 | 7 | 20.30 | 7.50 | 90 | 126 | 742 | 318 | 524 | 2277 | 150 | 2154 | 2632 | 479 | 18 | 21 |
| 21 | 7 | 20.00 | 6.30 | 96 | 126 | 758 | 667 | 840 | 2114 | 219 | 2433 | 2817 | 384 | 14 | 9 |
| 28 | 7 | 19.90 | 6.60 | 93 | 126 | 718 | 664 | 831 | 2306 | 227 | 2557 | 2735 | 178 | 6 | 8 |
| FEB 4 | 7 | 19.70 | 3.80 | 111 | 126 | 717 | 654 | 822 | 2103 | 273 | 2462 | 3270 | 807 | 25 | 36 |
| 11 | 7 | 19.60 | 3.90 | 110 | 126 | 839 | 643 | 831 | 2301 | 379 | 2705 | 3228 | 523 | 16 | 12 |
| 18 | 7 | 19.30 | 5.40 | 97 | 126 | 653 | 560 | 728 | 1572 | 226 | 1976 | 2858 | 883 | 31 | 7 |
| 26 | 8 | 19.80 | 7.40 | 99 | 144 | 785 | 610 | 811 | 1708 | 154 | 2075 | 2914 | 839 | 29 | 16 |
| MAR 4 | 6 | 18.80 | 6.00 | 77 | 108 | 712 | 599 | 754 | 1763 | 379 | 2279 | 2256 | -23 | -1 | 14 |
| 11 | 7 | 19.30 | 8.30 | 77 | 126 | 742 | 618 | 794 | 1335 | 152 | 1813 | 2262 | 449 | 20 | 15 |
| 18 | 7 | 19.20 | 8.10 | 78 | 126 | 774 | 576 | 761 | 1478 | 208 | 1929 | 2283 | 353 | 15 | 46 |
| 25 | 7 | 19.80 | 8.10 | 82 | 126 | 826 | 663 | 847 | 1517 | 167 | 2008 | 2406 | 406 | 17 | 44 |
| 31 | 6 | 19.60 | 8.40 | 67 | 108 | 643 | 565 | 713 | 1470 | 211 | 1879 | 1974 | 95 | 5 | 8 |
| APR 8 | 8 | 19.60 | 8.10 | 92 | 144 | 694 | 675 | 856 | 1826 | 365 | 2408 | 2703 | 295 | 11 | 51 |
| 15 | 7 | 19.60 | 7.00 | 88 | 126 | 618 | 643 | 797 | 2257 | 284 | 2548 | 2591 | 43 | 2 | 58 |
| 29 | 13 | 19.70 | 10.80 | 116 | 234 | 1287 | 1046 | 1368 | 1842 | 27 | 2593 | 3399 | 806 | 24 | 108 |
| TOTALS: | 174 | | | 2344 | 3132 | 18544 | 15887 | 20212 | 51607 | 5507 | 59263 | 68869 | 9606 | 14 | |
| MEANS: | | 19.58 | | | | | | | | | | | | | |
| TOTALS: (7 JAN-15 APR) | 98 | | | 1257 | 1764 | 10221 | 8455 | 10907 | 26027 | 3394 | 31218 | 36929 | 5710 | 15 | |

TABLE 10

RICHMOND SOLAR HOUSE ENERGY BALANCE
Occupied period

HLC (W/C) = 256 Furnace Eff. = .9

| PERIOD ENDING | DAYS IN PERIOD | INSIDE TEMP. (C) | OUTSIDE TEMP. (C) | DEGREE DAYS (DDC) | PEOPLE (MJ) | WATER DEMAND (MJ) | UTILITY (MJ) | INT. GAINS (MJ) | SPACE GAS (MJ) | SPACE ELECT. (MJ) | NON-SOL GAINS (MJ) | TOTAL LOAD (MJ) | SOLAR (MJ) | SOLAR (%) | BRIGHT SUN (hrs) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NOV 19 | 14 | 20.30 | 4.20 | 225 | 151 | 619 | 1209 | 1332 | 1347 | 651 | 3195 | 4985 | 1790 | 36 | 52 |
| 26 | 7 | 20.30 | 0.20 | 141 | 76 | 322 | 653 | 712 | 1213 | 436 | 2239 | 3112 | 873 | 28 | 27 |
| DEC 3 | 7 | 20.20 | 7.00 | 92 | 76 | 293 | 689 | 740 | 680 | 295 | 1647 | 2044 | 397 | 19 | 2 |
| 10 | 7 | 20.10 | 3.00 | 120 | 76 | 387 | 1111 | 1134 | 904 | 29 | 1976 | 2648 | 671 | 25 | 31 |
| 17 | 7 | 20.50 | 6.40 | 99 | 76 | 292 | 712 | 760 | 880 | 321 | 1873 | 2183 | 310 | 14 | 3 |
| 24 | 7 | 20.30 | 5.40 | 104 | 76 | 364 | 778 | 830 | 922 | 370 | 2030 | 2307 | 277 | 12 | 11 |
| 31 | 7 | 20.30 | 1.10 | 134 | 76 | 367 | 787 | 839 | 970 | 404 | 2116 | 2973 | 857 | 29 | 25 |
| JAN 7 | 7 | 20.40 | 5.30 | 106 | 76 | 369 | 677 | 740 | 1097 | 325 | 2053 | 2338 | 285 | 12 | 4 |
| 14 | 7 | 20.50 | 7.50 | 91 | 76 | 314 | 811 | 853 | 715 | 289 | 1785 | 2013 | 228 | 11 | 21 |
| 21 | 7 | 20.20 | 6.30 | 97 | 76 | 364 | 757 | 812 | 650 | 411 | 1800 | 2152 | 345 | 16 | 9 |
| 28 | 7 | 20.50 | 6.60 | 97 | 76 | 316 | 784 | 829 | 689 | 381 | 1830 | 2152 | 322 | 15 | 8 |
| FEB 4 | 7 | 19.80 | 3.80 | 112 | 76 | 324 | 716 | 769 | 686 | 293 | 1679 | 2477 | 798 | 32 | 36 |
| 11 | 7 | 19.70 | 3.90 | 111 | 76 | 271 | 693 | 740 | 1048 | 291 | 1974 | 2646 | 672 | 19 | 12 |
| 18 | 7 | 20.60 | 5.40 | 106 | 76 | 336 | 793 | 840 | 782 | 252 | 1796 | 2353 | 558 | 24 | 7 |
| 26 | 8 | 20.60 | 7.40 | 106 | 86 | 327 | 791 | 847 | 486 | 251 | 1536 | 2336 | 800 | 34 | 16 |
| MAR 4 | 6 | 20.30 | 6.00 | 86 | 65 | 301 | 767 | 800 | 694 | 301 | 1726 | 1898 | 172 | 9 | 14 |
| 11 | 7 | 20.40 | 8.30 | 85 | 76 | 259 | 709 | 753 | 523 | 277 | 1500 | 1873 | 373 | 20 | 15 |
| 25 | 14 | 20.80 | 8.10 | 178 | 151 | 585 | 1482 | 1573 | 638 | 489 | 2547 | 3933 | 1386 | 35 | 90 |
| 31 | 6 | 20.40 | 8.40 | 72 | 65 | 240 | 657 | 692 | 424 | 242 | 1316 | 1593 | 277 | 17 | 8 |
| APR 8 | 8 | 20.50 | 8.10 | 99 | 86 | 284 | 861 | 904 | 269 | 325 | 1471 | 2194 | 723 | 33 | 51 |
| 15 | 7 | 20.50 | 7.00 | 95 | 76 | 362 | 755 | 809 | 292 | 252 | 1324 | 2090 | 766 | 37 | 58 |
| 29 | 13 | 20.50 | 10.80 | 126 | 140 | 583 | 1325 | 1420 | 395 | 93 | 1869 | 2789 | 920 | 33 | 108 |
| TOTALS: | 174 | | | 2482 | 1879 | 7879 | 18517 | 19726 | 16294 | 6898 | 6898 | 54889 | 13600 | 25 | |
| MEANS: | | 20.35 | | | | | | | | | | | | | |
| TOTALS: (7 JAN-15 APR) | 98 | | | 1334 | 1058 | 4283 | 10576 | 11219 | 7886 | 3974 | 22291 | 29510 | 7220 | 24 | |

TABLE 11

RICHMOND CONSERVER HOUSE ENERGY BALANCE
Occupied period

HLC (W/C) = 200 Furnace Eff. = .9

| PERIOD ENDING | DAYS IN PERIOD | INSIDE TEMP. (C) | OUTSIDE TEMP. (C) | DEGREE DAYS (DDC) | PEOPLE (MJ) | WATER DEMAND (MJ) | UTILITY (MJ) | INT. GAINS (MJ) | SPACE GAS (MJ) | SPACE ELECT. (MJ) | NON-SOL GAINS (MJ) | TOTAL LOAD (MJ) | SOLAR (MJ) | (%) | BRIGHT SUN (hrs) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NOV 19 | 14 | 22.90 | 4.20 | 262 | 182 | 912 | 850 | 1126 | 2587 | 1050 | 4585 | 4524 | 19 | 0 | 52 |
| 26 | 7 | 22.00 | 8.20 | 158 | 91 | 499 | 513 | 653 | 1421 | 449 | 2381 | 2734 | 353 | 13 | 27 |
| DEC 3 | 7 | 23.60 | 7.00 | 116 | 91 | 456 | 905 | 639 | 1072 | 451 | 2055 | 2008 | -47 | -2 | 2 |
| 10 | 7 | 23.40 | 3.00 | 143 | 91 | 406 | 408 | 618 | 1277 | 385 | 2150 | 2468 | 318 | 13 | 31 |
| 17 | 7 | 23.80 | 6.40 | 122 | 91 | 464 | 491 | 627 | 1246 | 379 | 2127 | 2105 | -23 | -1 | 3 |
| 24 | 7 | 24.90 | 5.40 | 134 | 91 | 354 | 465 | 586 | 1447 | 486 | 2294 | 2310 | 16 | 1 | 11 |
| 31 | 7 | 23.10 | 1.10 | 154 | 91 | 354 | 465 | 586 | 1447 | 362 | 2250 | 2661 | 411 | 15 | 25 |
| JAN 7 | 7 | 22.90 | 5.30 | 123 | 91 | 401 | 533 | 658 | 1127 | 343 | 2015 | 2129 | 114 | 5 | 4 |
| 14 | 7 | 22.80 | 7.50 | 107 | 91 | 400 | 520 | 645 | 1015 | 286 | 1845 | 1851 | 6 | 0 | 21 |
| 21 | 7 | 23.30 | 6.30 | 119 | 91 | 380 | 433 | 559 | 1003 | 361 | 1823 | 2056 | 233 | 11 | 9 |
| 28 | 7 | 23.00 | 6.60 | 115 | 91 | 391 | 483 | 609 | 1109 | 301 | 1900 | 1984 | 76 | 4 | 8 |
| FEB 4 | 7 | 22.70 | 3.80 | 132 | 91 | 412 | 445 | 576 | 851 | 244 | 1585 | 2286 | 701 | 31 | 36 |
| 11 | 7 | 22.10 | 3.90 | 127 | 91 | 393 | 486 | 593 | 1111 | 315 | 1900 | 2201 | 294 | 13 | 12 |
| 18 | 7 | 22.50 | 5.40 | 120 | 91 | 475 | 508 | 645 | 956 | 230 | 1735 | 2068 | 333 | 16 | 7 |
| 26 | 8 | 22.80 | 7.40 | 123 | 104 | 436 | 482 | 626 | 831 | 245 | 1619 | 2129 | 510 | 24 | 16 |
| MAR 4 | 6 | 23.00 | 6.00 | 102 | 78 | 436 | 426 | 548 | 917 | 291 | 1664 | 1763 | 98 | 6 | 14 |
| 11 | 7 | 22.90 | 8.30 | 102 | 91 | 430 | 667 | 790 | 798 | 225 | 1734 | 1766 | 32 | 2 | 15 |
| 18 | 7 | 22.40 | 8.10 | 100 | 91 | 439 | 428 | 563 | 751 | 127 | 1366 | 1730 | 363 | 21 | 46 |
| 25 | 7 | 22.20 | 8.10 | 99 | 91 | 449 | 418 | 555 | 699 | 53 | 1230 | 1706 | 468 | 27 | 44 |
| 31 | 6 | 22.50 | 8.40 | 85 | 78 | 324 | 365 | 473 | 734 | 131 | 1265 | 1462 | 197 | 13 | 8 |
| APR 8 | 8 | 22.90 | 8.10 | 118 | 104 | 466 | 503 | 652 | 775 | 182 | 1531 | 2046 | 515 | 25 | 51 |
| 15 | 7 | 22.90 | 7.60 | 111 | 91 | 395 | 405 | 535 | 641 | 135 | 1247 | 1923 | 676 | 35 | 58 |
| 29 | 13 | 22.90 | 10.00 | 157 | 169 | 622 | 893 | 1141 | 409 | 367 | 1776 | 2718 | 942 | 35 | 108 |
| TOTALS: | 174 | | | 2930 | 2362 | 10492 | 11752 | 15000 | 24224 | 7218 | 44020 | 50627 | 6607 | 13 | |
| MEANS: | | 22.95 | | | | | | | | | | | | | |
| TOTALS: (7 JAN-15 APR) | 98 | | | 1581 | 1174 | 5824 | 6549 | 8369 | 12195 | 3126 | 22467 | 26971 | 4504 | 17 | |

TABLE 12

SAANICH CONTROL HOME ENERGY BALANCE
Occupied period HLC (W/C) = 359 Furnace eff. = 1.00

| PERIOD ENDING | DAYS IN PERIOD | INSIDE TEMP. (C) | OUTSIDE TEMP. (C) | DEGREE DAYS (DDC) | PEOPLE (MJ) | WATER DEMAND (MJ) | UTILITY (MJ) | INT. GAINS (MJ) | SPACE ELECT. (MJ) | NON-SOL GAINS (MJ) | TOTAL LOAD (MJ) | WOOD + SOLAR (MJ) | (%) | BRIGHT SUN (hrs) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JAN 14 | 7 | 22.50 | 7.50 | 105 | 126 | 657 | 787 | 933 | 104 | 1037 | 3257 | 2220 | 68 | 28 |
| 21 | 7 | 21.40 | 5.90 | 109 | 126 | 629 | 643 | 759 | 119 | 918 | 3365 | 2447 | 73 | 6 |
| 28 | 7 | 20.30 | 6.30 | 98 | 126 | 661 | 698 | 853 | 661 | 1514 | 3040 | 1525 | 50 | 6 |
| FEB 11 | 14 | 21.00 | 4.90 | 225 | 252 | 1260 | 1336 | 1643 | 1827 | 3470 | 6991 | 3521 | 50 | 49 |
| 25 | 14 | 20.80 | 8.10 | 178 | 252 | 1092 | 1225 | 1518 | 880 | 2398 | 5515 | 3117 | 57 | 24 |
| MAR 4 | 7 | 21.10 | 6.40 | 103 | 126 | 580 | 597 | 750 | 198 | 948 | 3192 | 2243 | 70 | 22 |
| 18 | 14 | 21.00 | 8.30 | 178 | 252 | 1220 | 1241 | 1552 | 550 | 2102 | 5515 | 3413 | 62 | 70 |
| 25 | 7 | 21.00 | 7.90 | 92 | 126 | 459 | 491 | 637 | 390 | 1027 | 2544 | 1818 | 64 | 47 |
| APR 15 | 21 | 21.00 | 7.60 | 281 | 378 | 1853 | 1687 | 2174 | 716 | 2890 | 8728 | 5838 | 67 | 130 |
| TOTALS: | 98 | | | 1369 | 1764 | 8411 | 8705 | 10860 | 5445 | 16305 | 42448 | 26142 | 62 | |
| MEANS: | | 21.12 | | | | | | | | | | | | |

Note that, due to the uncontrolled nature of wood use, and uncertain efficiency of wood appliances, wood fuel content, etc., the wood heating energy supplied has been combined with the solar. Assuming a solar contribution of about 6 to 7 GJ for the period (typical of the other houses), wood heat must have supplied just under 20 GJ. This is consistent with the 1 to 2 cords of wood consumed in the air tight wood stove.

TABLE 13

SAANICH SOLAR HOME ENERGY BALANCE
Occupied period HLC (W/C) = 312 Furnace eff. = 0.95

| PERIOD ENDING | DAYS IN PERIOD | INSIDE TEMP. (C) | OUTSIDE TEMP. (C) | DEGREE DAYS (DDC) | PEOPLE (MJ) | WATER DEMAND (MJ) | UTILITY (MJ) | INT. GAINS (MJ) | SPACE ELECT. (MJ) | NON-SOL GAINS (MJ) | TOTAL LOAD (MJ) | SOLAR (MJ) | (%) | BRIGHT SUN (hrs) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JAN 14 | 7 | 20.50 | 7.50 | 91 | 151 | 432 | 556 | 744 | 1415 | 2088 | 2453 | 365 | 15 | 28 |
| 21 | 7 | 20.40 | 5.90 | 102 | 151 | 443 | 594 | 782 | 1987 | 2670 | 2736 | 67 | 2 | 6 |
| 28 | 7 | 19.90 | 6.30 | 95 | 151 | 466 | 572 | 765 | 2035 | 2698 | 2566 | -131 | -5 | 6 |
| FEB 11 | 14 | 20.10 | 4.90 | 213 | 302 | 892 | 1085 | 1467 | 3462 | 4756 | 5736 | 981 | 17 | 49 |
| 25 | 14 | 19.90 | 8.10 | 165 | 302 | 787 | 1078 | 1445 | 2690 | 4000 | 4453 | 453 | 10 | 24 |
| MAR 4 | 7 | 20.20 | 6.40 | 97 | 151 | 411 | 561 | 750 | 1220 | 1909 | 2604 | 695 | 27 | 22 |
| 18 | 14 | 20.50 | 8.30 | 171 | 302 | 821 | 1064 | 1436 | 1358 | 2726 | 4604 | 1878 | 41 | 70 |
| 25 | 7 | 20.60 | 7.90 | 90 | 151 | 424 | 536 | 724 | 302 | 1011 | 2434 | 1423 | 58 | 47 |
| APR 15 | 21 | 21.00 | 7.60 | 281 | 454 | 1367 | 1741 | 2313 | 2123 | 4329 | 7586 | 3256 | 43 | 130 |
| TOTALS: | 98 | | | 1305 | 2117 | 6043 | 7791 | 10425 | 16592 | 26187 | 35173 | 8986 | 26 | |
| MEANS: | | 20.37 | | | | | | | | | | | | |

It should be noted that the calculated solar contribution, since it equals the difference between total load and non-solar gains, is dependent upon:

a) Building HLC
b) Inside to outside temperature difference
c) Internal gains (utilities, people gains, etc.)

The same building will, therefore, have different solar contributions with different occupants.

All the totals (fuel consumption, solar contribution, etc.) are for conditions as monitored and for only a portion of the year. Economic evaluations require full year results under long term average weather conditions and house to house comparisons require standardized operating conditions - particularly inside temperature and internal gains.

Economic evaluations and system comparisons can be carried out through the use of accurate computer modelling in which predicted values under actual conditions are first compared with monitored energy consumption. After a successful correlation, predictions of energy use with long term average weather conditions can then be performed with reasonable confidence. The results of such a comparison have been performed in Appendix A and the results presented in Table 14 for the Richmond houses. Predictions were not performed for the Saanich houses due to the lack of good monitored results for the Control and Conserver houses.

TABLE 14

Predicted Energy Use (see Appendix A)

| House | Actual* Fuel (GJ) | Predicted* Fuel (GJ) | Difference (GJ) | Difference (%) | Long Term Predicted Annual Fuel** (GJ) | Fuel Savings** over Richmond control (GJ) | Fuel Savings** over Richmond control (%) |
|---|---|---|---|---|---|---|---|
| Richmond | | | | | | | |
| Control | 57.1 | 62.7 | 5.6 | +10 | 117 | - | - |
| Solar | 23.2 | 26.2 | 3.0 | +13 | 48 | 69 | 59 |
| Conserver | 31.4 | 33.7 | 2.3 | + 7 | 40 | 77 | 66 |

As can be seen from the table, comparison of monitored results would have shown the Solar house to have outperformed the Conserver, while under standardized conditions, the reverse is the case.

Predicted fuel consumption was consistently about 10% higher than actual. While this error is higher than desired, it is within acceptable limits. Long term comparisons are therefore possible and show about 60% reduction relative to the Control.

* Fuel use for monitored conditions and period: Richmond - November 5, 1982 to April 29, 1983.

** For standard inside conditions (see Appendix A, page A4):
Inside temperature = 21°C
Internal gains = 1000W
and long term average Vancouver weather conditions.

## 4.0 CONCLUSIONS

Direct house to house comparisons of monitored data are not generally possible due to variations in inside temperatures and internal gains. Such comparisons can be made, however, through the use of performance prediction models that have been verified against the monitored data.

While monitoring equipment should be installed at the time of construction*, the actual monitoring should not begin until the building is occupied.

According to prediction, the Richmond Solar and Conserver save about 59% and 66% respectively, relative to the Control. It should be noted that the Richmond Control is significantly more airtight than is typical for new Vancouver housing.

The Saanich Solar and Richmond Solar had (coincidentally) almost identical conditions of inside temperature and internal gains, yet the former used about 40% more energy than the latter for the same period**.

The damper connecting the Richmond Solar greenhouse to the return air was not recorded as having opened for the entire monitored period. If it were functioning, the greenhouse would have contributed more heat than was observed and the total solar contribution would increase.

* In fact, the monitoring system design should be incorporated into the building design (to allow for easy sub-metering of certain circuits, for example).

** See Tables 10 and 13 (7 January to 15 April, 1983). The Saanich Solar, with 7% less heated floor area, had a 22% higher heat loss coefficient than the Richmond Solar.

## 5.0 ACKNOWLEDGEMENTS

This monitoring program was funded by the B.C. Ministry of Energy, Mines and Petroleum Resources. The cooperation and suggestions of Mr. Ray Fung are particularly appreciated. We are particularly grateful to Dr. John Hay, UBC Dept. of Geography, for supplying local measured insolation data and assistance in checking the calibration of the pyranometer. Our appreciation also goes to the owners of the houses for their patience and understanding.

## APPENDIX A - PERFORMANCE PREDICTIONS

Richmond Control House - Comparison of Predicted to Actual, 5 Nov 82 to 29 Apr 83 with operating conditions as monitored.

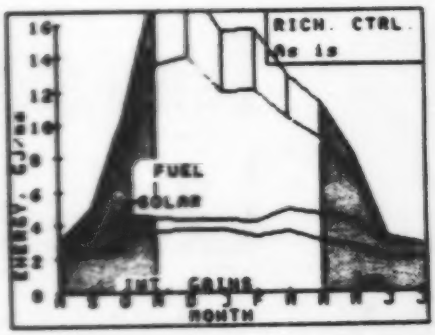
| RICHMOND CONTROL | | | FILE |
|---|---|---|---|
| Monitored Conditions | | | R2 |
| Inside Temp. | DAY | C | 19.6 |
| | NIGHT | C | 19.6 |
| Loss Coeff.. | DAY | W/C | 340 |
| | NIGHT | W/C | 340 |
| Int Gains. | DAY | kW | 1.34 |
| | NIGHT | kW | 1.34 |
| Mass Factor | | | 0 |
| Furnace size/Effic. kW | | | 20 / 60 |

| TYPE | AREA | NR | AZ. | SLOPE | ABS |
|---|---|---|---|---|---|
| DG | 5.2 | 2 | 0 | 90 | 90 |
| DG | 8.4 | 2 | 180 | 90 | 95 |
| DG | 2.4 | 2 | 90 | 90 | .8 |
| DG | 0 | 2 | 180 | 90 | .9 |
| DG | 0 | 2 | 180 | 45 | .8 |

SPACE HEAT (GJ)

| MO | LOAD | INT. | SOLAR | DEMAND | FUEL |
|---|---|---|---|---|---|
| [illegible] | | | | | |
| N | 13.6 | 3.6 | 0.0 | 9.2 | 13.5 |
| D | 14.0 | 3.7 | 0.7 | 9.7 | 14.2 |
| J | 12.0 | 3.7 | 0.6 | 7.7 | 11.4 |
| F | 12.0 | 3.4 | 0.9 | 7.8 | 11.5 |
| M | 10.4 | 3.6 | 1.3 | 5.5 | 8.1 |
| A | 9.2 | 3.0 | 1.6 | 4.5 | 6.7 |
| [illegible] | | | | | |
| 5 Nov 82 to 29 Apr 83 | | | | | |
| | 68.5 | 20.3 | 5.7 | 42.6 | 62.7 |
| Monitored | 68.9 | 20.2 | 9.6 | 39.0 | 57.1 |

Difference in fuel (GJ) 5.6
(%) +10



**Richmond Solar House - Comparison of Predicted to Actual, 5 Nov 82 to 29 Apr 83 with operating conditions as monitored.**

| RICHMOND SOLAR | | | FILE |
|---|---|---|---|
| Monitored Conditions | | | R1 |
| Inside Temp. | DAY | C | 20.3 |
| | NIGHT | C | 20.3 |
| Loss Coeff. | DAY | W/C | 256 |
| | NIGHT | W/C | 256 |
| Int Gains. | DAY | kW | 1.31 |
| | NIGHT | kW | 1.31 |
| Mass Factor | | | 8 |
| Furnace size/Effic. | | kW | 20 /.93 |

| TYPE | AREA | HR | AZ. | SLOPE | ABS |
|---|---|---|---|---|---|
| DG | 5.2 | 3 | 0 | 90 | .90 |
| DGHI | 9.7 | 2 | 180 | 90 | .95 |
| DG | 2.4 | 3 | 90 | 90 | .8 |
| GA | 9.1 | 2 | 180 | 90 | .9 |
| GA | 4.6 | 2 | 180 | 30 | .8 |

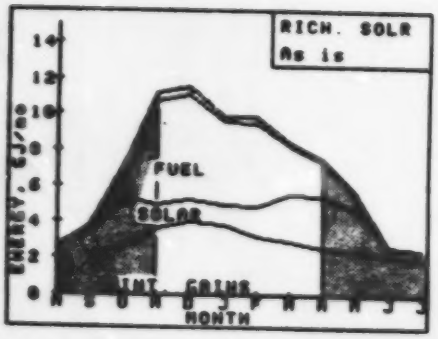
SPACE HEAT (GJ)

| MO | LOAD | INT. | SOLAR | DEMAND | FUEL |
|---|---|---|---|---|---|
| [redacted] | | | | | |
| N | 10.7 | 3.6 | 1.3 | 5.8 | 6.2 |
| D | 11.0 | 4.0 | 1.2 | 5.8 | 6.3 |
| J | 9.5 | 3.8 | 1.2 | 4.6 | 4.9 |
| F | 9.5 | 3.2 | 1.7 | 4.6 | 4.9 |
| M | 8.3 | 2.9 | 2.7 | 2.7 | 3.0 |
| A | 7.4 | 2.6 | 2.9 | 1.9 | 2.1 |
| [redacted] | | | | | |

5 Nov 82 to 29 Apr 83

| | | | | | |
|---|---|---|---|---|---|
| | 54.3 | 19.4 | 10.7 | 24.2 | 26.2 |
| Monitored | 54.9 | 19.7 | 13.6 | 21.6 | 23.2 |

Difference in fuel (GJ) 3.0
(%) +13



Richmond Conserver - Comparison of Predicted to Actual, 5 Nov 82 to 29 Apr 83 with operating conditions as monitored.

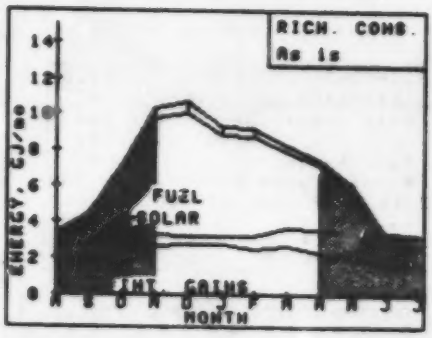
| RICHMOND CONSERVER | | | FILE |
|---|---|---|---|
| Monitored Conditions | | | RB |
| Inside Temp. | DAY | C | 23 |
| | NIGHT | C | 23 |
| Loss Coeff. | DAY | W/C | 200 |
| | NIGHT | W/C | 200 |
| Int. Gains. | DAY | kW | 1 |
| | NIGHT | kW | 1 |
| Mass Factor | | | 0 |
| Furnace size/Effic. | | kW | 20 /.92 |

| TYPE | AREA | HR | AZ. | SLOPE | ABS |
|---|---|---|---|---|---|
| DG | 5.2 | 3 | 0 | 90 | .90 |
| DG | 8.4 | 3 | 180 | 90 | .95 |
| DG | 2.4 | 3 | 90 | 90 | .8 |
| DG | 0 | 2 | 180 | 90 | .9 |
| DG | 0 | 2 | 180 | 45 | .8 |

SPACE HEAT (GJ)

| MO | LOAD | INT. | SOLAR | DEMND | FUEL |
|---|---|---|---|---|---|
| N | 9.7 | 2.6 | 0.6 | 6.5 | 7.0 |
| D | 10.1 | 2.7 | 0.5 | 6.8 | 7.4 |
| J | 8.8 | 2.7 | 0.5 | 5.6 | 6.1 |
| F | 8.7 | 2.5 | 0.7 | 5.6 | 6.1 |
| M | 7.9 | 2.6 | 1.1 | 4.2 | 4.6 |
| A | 7.2 | 2.2 | 1.3 | 3.6 | 3.9 |
| 5 Nov 82 to 29 Apr 83 | | | | | |
| | 50.5 | 14.8 | 4.6 | 31.0 | 33.7 |
| Monitored | | | | | |
| | 50.6 | 15.0 | 6.6 | 29.0 | 31.4 |

Difference in fuel (GJ) 2.3
(%) + 7



**RICHMOND**

Predicted Performance using 'Standard' internal conditions and long term Vancouver weather.

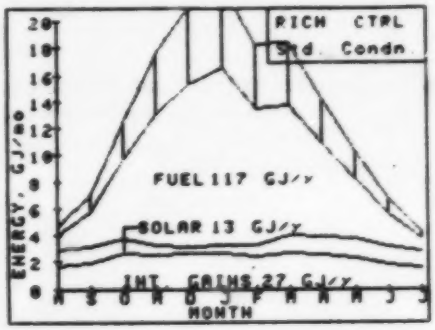
| RICHMOND CONTROL 'Standard' Conditions | | | FILE RS |
|---|---|---|---|
| Inside Temp. | DAY | C | 21 |
| | NIGHT | C | 21 |
| Loss Coeff. | DAY | W/C | 340 |
| | NIGHT | W/C | 340 |
| Int Gains. | DAY | kW | 1 |
| | NIGHT | kW | 1 |
| Mass Factor | | | 0 |
| Furnace size/Effic. kW 20 /.60 | | | |

| TYPE | AREA | HR. | AZ | SLOPE | ABS |
|---|---|---|---|---|---|
| DG | 5.2 | 2 | 0 | 90 | .90 |
| DG | 8.4 | 2 | 180 | 90 | .95 |
| DG | 2.4 | 2 | 90 | 90 | .8 |

SPACE HEAT (GJ)

| MO | LOAD | INT | SOLAR | DEMND | FUEL |
|---|---|---|---|---|---|
| A | 4.0 | 1.6 | 1.3 | 1.1 | 1.7 |
| S | 5.7 | 1.9 | 1.3 | 2.5 | 3.7 |
| O | 9.7 | 2.6 | 1.1 | 5.9 | 8.7 |
| N | 13.0 | 2.5 | 0.7 | 9.7 | 14.3 |
| D | 15.4 | 2.6 | 0.6 | 12.2 | 17.9 |
| J | 16.6 | 2.6 | 0.7 | 13.3 | 19.5 |
| F | 13.5 | 2.4 | 0.9 | 10.2 | 15.0 |
| M | 13.0 | 2.6 | 1.3 | 9.8 | 14.4 |
| A | 10.9 | 2.5 | 1.4 | 7.0 | 10.3 |
| M | 8.2 | 2.3 | 1.5 | 4.4 | 6.5 |
| J | 5.6 | 1.9 | 1.3 | 2.4 | 3.5 |
| J | 3.8 | 1.6 | 1.3 | 0.9 | 1.4 |
| | 120. | 27. | 13. | 80. | 117. |

COST (Fuel $ 4.39/GJ) $ 514/yr



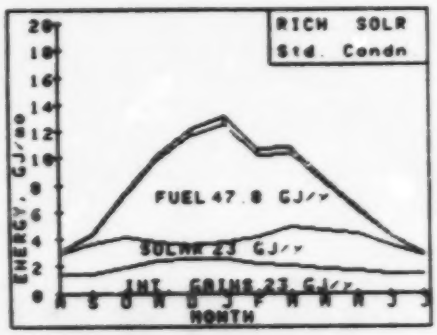

| RICHMOND SOLAR 'Standard' Conditions | | | FILE RS |
|---|---|---|---|
| Loss Coeff. | DAY | W/C | 256 |
| | NIGHT | W/C | 256 |
| Mass Factor | | | 0 |
| Furnace size/Effic. kW 20 /.93 | | | |

| TYPE | AREA | HR. | AZ. | SLOPE | ABS. |
|---|---|---|---|---|---|
| DG | 5.2 | 3 | 0 | 90 | .90 |
| DGHI | 9.7 | 2 | 180 | 90 | .95 |
| DG | 2.4 | 3 | 90 | 90 | .8 |
| GA | 9.1 | 2 | 180 | 90 | .9 |
| GA | 4.6 | 2 | 180 | 30 | .8 |

SPACE HEAT (GJ)

| MO | LOAD | INT | SOLAR | DEMND | FUEL |
|---|---|---|---|---|---|
| A | 3.0 | 1.4 | 1.5 | 0.1 | 0.2 |
| S | 4.3 | 1.5 | 2.2 | 0.7 | 0.7 |
| O | 7.3 | 1.9 | 2.3 | 3.1 | 3.3 |
| N | 9.8 | 2.5 | 1.3 | 6.0 | 6.5 |
| D | 11.6 | 2.6 | 1.0 | 8.1 | 8.7 |
| J | 12.5 | 2.6 | 1.2 | 8.7 | 9.4 |
| F | 10.2 | 2.2 | 1.9 | 6.0 | 6.5 |
| M | 10.4 | 2.1 | 2.0 | 5.5 | 5.9 |
| A | 8.2 | 1.8 | 2.0 | 3.6 | 3.9 |
| M | 6.2 | 1.7 | 2.7 | 1.8 | 1.9 |
| J | 4.2 | 1.5 | 2.0 | 0.7 | 0.8 |
| J | 2.8 | 1.4 | 1.4 | 0.1 | 0.1 |
| | 90.4 | 23.0 | 23.0 | 44.4 | 47.8 |

COST (Fuel $ 4.39/GJ) $ 210/yr



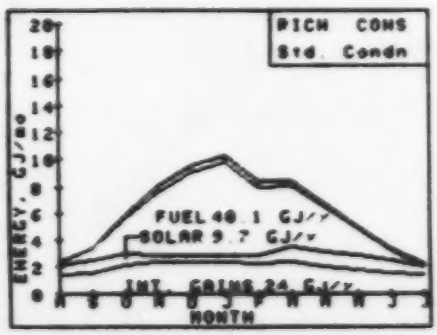

| RICHMOND CONSERVER 'Standard Conditions' | | | FILE RS |
|---|---|---|---|
| Loss Coeff. | DAY | W/C | 200 |
| | NIGHT | W/C | 200 |
| Mass Factor | | | 0 |
| Furnace size/Effic. kW 20 /.92 | | | |

| TYPE | AREA | HR | AZ. | SLOPE | ABS. |
|---|---|---|---|---|---|
| DG | 5.2 | 3 | 0 | 90 | .90 |
| DG | 8.4 | 3 | 180 | 90 | .95 |
| DG | 2.4 | 3 | 90 | 90 | .0 |

SPACE HEAT (GJ)

| MO | LOAD | INT. | SOLAR | DEMND | FUEL |
|---|---|---|---|---|---|
| A | 2.4 | 1.4 | 0.7 | 0.2 | 0.2 |
| S | 3.4 | 1.6 | 1.0 | 0.8 | 0.9 |
| O | 5.7 | 2.2 | 0.9 | 2.7 | 2.9 |
| N | 7.6 | 2.4 | 0.5 | 4.7 | 5.1 |
| D | 9.1 | 2.5 | 0.4 | 6.2 | 6.7 |
| J | 9.7 | 2.5 | 0.5 | 6.8 | 7.4 |
| F | 8.0 | 2.2 | 0.7 | 5.0 | 5.4 |
| M | 8.1 | 2.5 | 1.1 | 4.6 | 5.0 |
| A | 6.4 | 2.1 | 1.1 | 3.2 | 3.5 |
| M | 4.8 | 1.8 | 1.1 | 1.9 | 2.0 |
| J | 3.3 | 1.6 | 0.9 | 0.8 | 0.8 |
| J | 2.2 | 1.4 | 0.7 | 0.1 | 0.2 |
| | 70.7 | 24.1 | 9.6 | 37.0 | 40.2 |

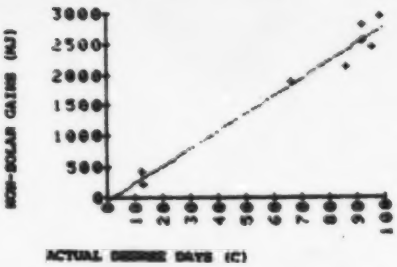
COST (Fuel $ 4.39/GJ) $ 176/yr



# APPENDIX B - HEAT LOSS COEFFICIENT CORRELATIONS
(See Sec. 3.5.2)

RICHMOND CONTROL

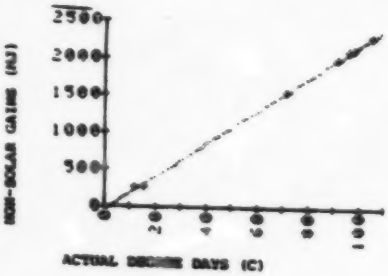
Regression Analysis: Furnace Efficiency 65%




| Constant * MJ | Slope MJ/DD | Slope W/C | Correlation Coefficient |
|---|---|---|---|
| -65 | 29 | 340 | .983 |

RICHMOND SOLAR

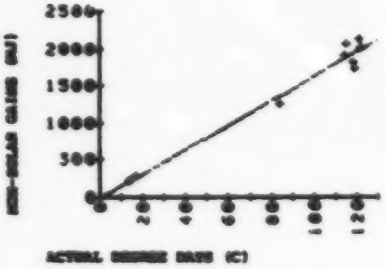
Regression Analysis: Furnace Efficiency 90%




| Constant * MJ | Slope MJ/DD | Slope W/C | Correlation Coefficient |
|---|---|---|---|
| -52 | 22 | 256 | .9986 |

RICHMOND CONSERVER

Regression Analysis: Furnace Efficiency 90%

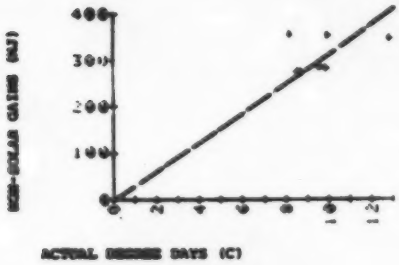



| Constant * MJ | Slope MJ/DD | Slope W/C | Correlation Coefficient |
|---|---|---|---|
| -36 | 19 | 200 | .996 |

* Constant is due to small solar gains during these periods.

**BRANCH CONTROL**

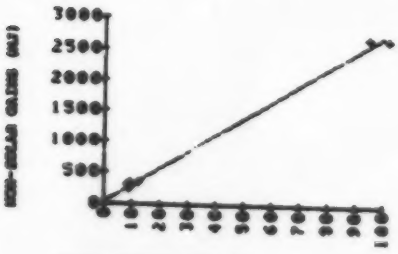
**Regression Analysis:Furnace Efficiency 100%**




| Constant * MJ | Slope MJ/DD | Slope W/C | Correlation Coefficient |
|---|---|---|---|
| 0 ** | 31 | 359 | --- *** |

**BRANCH SOLAR**

**Regression Analysis:Furnace Efficiency 90%**

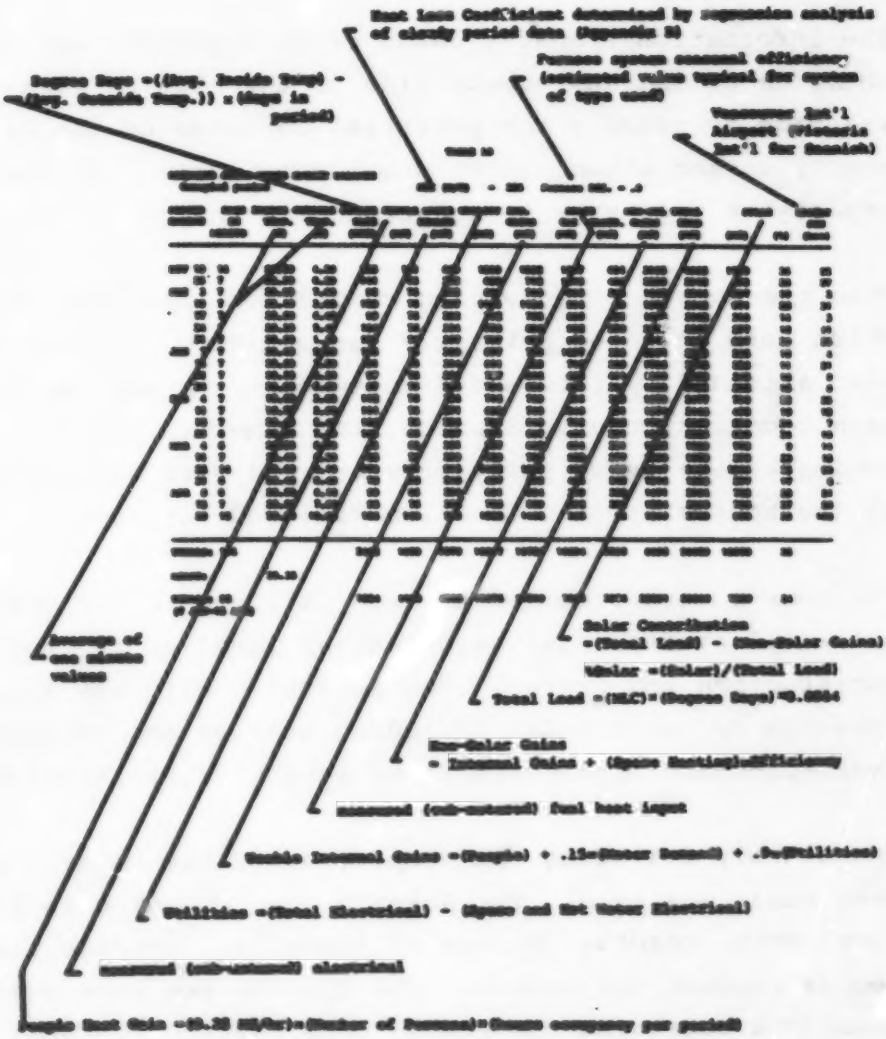



| Constant * MJ | Slope MJ/DD | Slope W/C | Correlation Coefficient |
|---|---|---|---|
| 20 | 27 | 312 | .998 |

** Assumed.

*** Regression analysis not significant due to limited range of degree days in sample.

# APPENDIX C - ENERGY BALANCE TERMINOLOGY



## APPENDIX B

### Information Transfer

The information transfer phase of this project was targetted at both the demand and supply side of the housing market. An effort was made to educate the potential consumer of the benefits of energy conservation and to provide builders with the knowledge and experience necessary to construct low energy houses.

When the houses were nearing completion, seminars were held, which were intended primarily for builders and designers but were also attended by interested homeowners. A seminar was held at each location, one in Saanich, the other in Richmond. The seminars were technically oriented and were well attended. A tour of the houses at each location followed the seminar.

The houses were promoted through mailings to the membership of trade and professional associations involved in residential construction and design. The general public was informed through coverage by local media including stories and advertisements in newspapers and announcements by several radio stations.

Immediately following the completion of the houses, a one month open house was held. The Saanich open houses coincided with the local HUDAC chapter "Parade of Homes" to increase the draw of people through the houses. The open houses were staffed to answer questions regarding the energy conservation features of the house. Pamphlets and publications by the Conservation and Renewable Energy Branch describing the houses and other general areas of residential energy conservation were distributed.

A sign was posted in front of each houses indicating the sponsors, that it was a CREDA project and that the house was part of the Low Energy Housing Demonstration Project.

A summary sheet has also been produced which will be made available to other government agencies, the industry and the general public.

The primary target audiences are listed as follows:

A. Housing and Urban Development Association of Canada,
British Columbia Council
# 3-15355 - 102 A Avenue
Surrey, B.C.
V3R 7K1
Telephone No. 584-1855

B. British Columbia Real Estate Assocition
#105 - 1847 W. Broadway
Vancouver, B.C.
V6J 1Y6
Telephone No. 731-2196

C. Architectural Institute of B.C.
970 Richards Street
Vancouver, B.C.
V6B 3C1

D. Canada Mortgage and Housing Corporation
#800 - 1500 W. Georgia Street
Vancouver, B.C.
V6G 3A1
Telephone No. 666-2943

E. Malaspina College
Energy Technology Program
900 5th Street
Nanaimo, B.C.
Telephone No. 753-3245

F. Carpenters District Council
#3-2806 Kingsway
Vancouver, B.C.
V5R 5H8
Telephone No. 438-1655

G. Insulation Applicators Association of B.C.
3785 Myrtle Street
Burnaby, B.C.
V5C 4E7
Telephone No. 430-1353